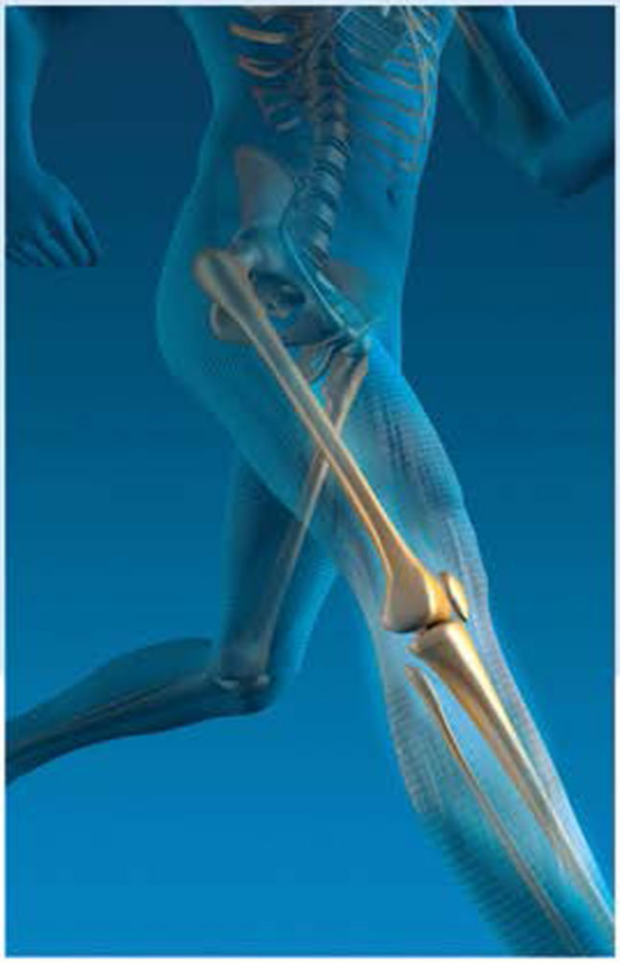

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SPORTS MEDICINE

LYLE J. MICHELI, M.D., EDITOR

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SAGE | reference

Los Angeles | London | New Delhi
Singapore | Washington DC

For information:

SAGE Publications, Inc.
2455 Teller Road
Thousand Oaks, California 91320
E-mail: order@sagepub.com

SAGE Publications Ltd.
1 Oliver's Yard
55 City Road
London, EC1Y 1SP
United Kingdom

SAGE Publications India Pvt. Ltd.
B 1/I 1 Mohan Cooperative Industrial Area
Mathura Road, New Delhi 110 044
India

SAGE Publications Asia-Pacific Pte. Ltd.
33 Pekin Street #02-01
Far East Square
Singapore 048763

Printed in the United States of America.

Library of Congress Cataloging-in-Publication Data

Encyclopedia of sports medicine / edited by Lyle J. Micheli.
p. cm.
"A SAGE Reference Publication."
Includes bibliographical references and index.
ISBN 978-1-4129-6115-8 (cloth)
1. Sports medicine—Encyclopedias. 2. Sports injuries—Encyclopedias. I. Micheli, Lyle J., 1940–[DNLM: 1. Sports Medicine—Encyclopedias—English. 2. Athletic Injuries—Encyclopedias—English. 3. Sports—Encyclopedias—English. QT 13 E5298 2011]

RC1206.E53 2011
617.1′02703—dc22 2010023364

10 11 12 13 14 10 9 8 7 6 5 4 3 2 1

Publisher: Rolf A. Janke
Acquisitions Editor: Jim Brace-Thompson
Assistant to the Publisher: Michele Thompson
Developmental Editor: Sanford Robinson
Reference Systems Coordinator: Laura Notton
Reference Systems Manager: Leticia M. Gutierrez
Production Editor: Kate Schroeder
Copy Editors: QuADS Prepress (P) Ltd.
Typesetter: C&M Digitals (P) Ltd.
Proofreaders: Kristin Bergstad, Scott Oney, Christina West
Indexer: Virgil Diodato
Cover Designer: Gail Buschman

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About the Editor

Lyle J. Micheli, M.D., is one of the world's leading experts in sports medicine. He is a clinical professor of orthopaedic surgery at Harvard Medical School and the O'Donnell Family Professor of Orthopaedic Sports Medicine at Children's Hospital Boston. Dr. Micheli cofounded the world's first pediatric sports medicine clinic, the Division of Sports Medicine, at the Children's Hospital Boston in 1974, and he remains its director to this day. Dr. Micheli oversees the clinic's mission to treat child and adolescent patients with injuries of an orthopaedic nature and to sponsor research into the mechanisms of sports injuries, the techniques of rehabilitation and treatment, and the physiology of exercise and conditioning. In addition to directing the Division (which also specializes in dance medicine), Dr. Micheli has been the attending physician for the Boston Ballet since 1977.

Associations such as the American Academy of Orthopaedic Surgeons, the Chinese Association of Sports Medicine, the National Center for Sports Safety, and the International Olympic Committee have invited Dr. Micheli to speak and teach courses. In 2010, he became the Secretary General of the International Federation of Sports Medicine, having long been associated with that venerable organization, which predates even the International Olympic Committee Medical Association. Thanks to this association, Dr. Micheli has become even better known as a lecturer around the world.

Closer to home, Dr. Micheli is also a former president of the American College of Sports Medicine, former chairman of Massachusetts Governor's Council on Fitness and Sports, and a founder of the National Youth Sports Safety Foundation. He maintains a very active clinical practice at Boston Children's Hospital. Dr. Micheli personally sees between 170 and 200 patients every week. In addition, he performs an average of 1,100 surgical operations annually.

An able athlete himself, in the 1960s, Dr. Micheli represented Harvard College as an undergraduate in football, rugby, lacrosse, and boxing, while still finding the time to graduate *cum laude*. Dr. Micheli remains active in the rugby community and has served as medical director of the United States's national governing body for the sport.

Dr. Micheli is the author of an extensive number of scholarly articles. He has written five books for a general audience including *The Sports Medicine Bible* (1995) and *The Sports Medicine Bible for Young Athletes* (2001). He has also written or edited numerous academic texts. He is married to Anne and has two daughters who maintain an active interest in sports and dance. He resides in Brookline, Massachusetts, close enough to Children's Hospital Boston to bicycle to work when the New England weather is clear—and often when it isn't.

Among Dr. Micheli's many professional activities, awards, and achievements to date are the following:

- Medical Team, Boston Marathon, Finish Line Director
- Attending Physician, Boston Ballet
- Team Physician, U.S. Figure Skating Association
- Chair, Medical and Risk Management Committee, U.S.A. Rugby
- Honorary Member, National Athletic Trainers Association
- Fitness Practitioner Advisory Board, Aerobics and Fitness Association of America
- Advisory Council, Massachusetts Special Olympics

- Serves on the Editorial/Advisory Boards for more than 20 journals
- Leader, Citizen Ambassador Program Sports Medicine Delegation to East Germany and the Soviet Union
- Citation Award, American College of Sports Medicine
- Medal of Honor, Boston Ballet
- President's Award, Massachusetts Association of Health, Physical Education, Recreation and Dance
- William G. Anderson Award, American Alliance for Health, Physical Education, Recreation and Dance
- Gold Star State Council Member of the Year, National Association of Governor's Councils on Physical Fitness and Sports
- Inaugural Inductee to Athletic Trainers Massachusetts Hall of Fame
- St. Bede Academy, Peru, Illinois, Athletic Hall of Fame Inductee
- American Academy of Pediatrics Thomas E. Schaffer Award recipient (for lifetime contributions to the field of Sports Medicine)
- Given more than 100 lectures or speaking engagements since 2000
- Published nearly 150 refereed journal articles
- Published more than 100 non-refereed articles

About the Advisory Board

James R. Andrews is a founding member of Andrews Sports Medicine and Orthopaedic Center in Birmingham, Alabama, and a founder and Medical Director of the American Sports Medicine Institute (ASMI), a nonprofit institute dedicated to injury prevention, education, and research in orthopaedics and sports medicine. Through ASMI he has mentored more than 250 orthopaedic/sports medicine Fellows and more than 45 primary care sports medicine Fellows. Dr. Andrews is also a founding partner and Medical Director of the Andrews Institute and Andrews-Paulos Research and Education Institute in Gulf Breeze, Florida. A native of Homer, Louisiana, he graduated from Louisiana State University (LSU) in 1963, where he was Southeastern Conference pole vault champion. He completed LSU School of Medicine in 1967 and his orthopaedic residency at Tulane Medical School in 1972. He is a member of the American Board of Orthopaedic Surgery and the American Academy of Orthopaedic Surgeons and served as the 2009–2010 President of the American Orthopaedic Society for Sports Medicine. He is Clinical Professor of Orthopaedic Surgery at the University of Alabama Birmingham Medical School, the University of Virginia School of Medicine, the University of Kentucky Medical Center, and the University of South Carolina Medical School. Dr. Andrews provides coverage to several collegiate and professional teams including Auburn University, the University of Alabama, the Washington Redskins, the Tampa Bay Rays, and the LPGA. He also serves on the Board of Little League Baseball. Dr. Andrews has been inducted into both Alabama and Louisiana's state Sports Halls of Fame.

John Bergfeld is the former Head of Sports Medicine and now is Senior Surgeon, Department of Orthopaedics and Director of the Operating Rooms at the Cleveland Clinic, Cleveland, Ohio. Dr. Bergfeld served in the U.S. Navy as Chief of Orthopaedics of the United States Naval Academy, U.S. Naval Hospital, Annapolis, Maryland and aboard the U.S.S. Dubuque (1970–1973) with rank—Commander MC USNR. He served as a President of the American College of Sports Medicine (1984–1985) and as President of the American Orthopaedic Society for Sports Medicine (1992–1993). He served as Team Physician for the Cleveland Browns (NFL; 1976–2002), as Team Physician for the Cleveland Cavaliers (NBA; 1986–2001), as Physician to Cleveland Ballet (1976–1990), at Baldwin Wallace College (1996–present) and at the Cleveland Metropolitan Schools (1976–present). He has received numerous awards and honors and presently serves as consultant to the Cleveland Browns and Cavaliers. Dr. Bergfeld founded the Cleveland Rugby Football Club in 1964.

Arthur L. Boland received his M.D. from Cornell University Medical College in1961. After an internship and assistant residency in general surgery at New York Hospital-Cornell Medical Center, he served in the U.S. Army in Germany for two years. He completed the Harvard Combined Orthopaedic Residency Program in 1969. Dr. Boland is an assistant clinical professor of Orthopaedic Surgery at Harvard Medical School, Chief of Orthopaedic Surgery at the Harvard University Health Services, and Emeritus Head Surgeon for the Harvard Athletic Department. Dr. Boland has been an assistant team physician for the New England Patriots and Boston Bruins and was a member of the medical staff of the 1984 Olympic Games. He has also served as team physician for the U.S. Hockey Team at the World Championships in 1993 and has been an orthopedic consultant for the U.S. Rowing Team. Dr. Boland has served on numerous committees for several professional organizations, including the American Academy of Orthopedic Surgeons Committee on Sports Medicine and its Committee on Outcomes Research. He has been President and a member of the Board of Directors of the American Orthopaedic Society for Sports Medicine, President of the Herodicus Society, and a member of the program committee of the International Cartilage Repair Society, and he has served on the Strategic Planning and Membership Committees of the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine. In 2000 Dr. Boland was the recipient of the American Orthopaedic Society for Sports Medicine's "Mr. Sports Medicine Award: In Recognition and Appreciation for his Outstanding and Meritorious Service to Sports Medicine Throughout the World." In 2005 he was inducted into the American Orthopaedic Society for Sports Medicine's Hall of Fame, the Society's highest honor.

Robert C. Cantu holds many professional responsibilities, including those of Clinical Professor, Department of Neurosurgery and Co-Director Center for the Study of Traumatic Encephalopathy, Boston University School of Medicine; Senior Advisor to the NFL Head, Neck and Spine Committee; Founding member and Chairman of the Medical Advisory Board Sports Legacy Institute; Adjunct Professor of Exercise and Sport Science and Medical Director of the National Center for Catastrophic Sports Injury Research, University of North Carolina; Co-Director, Neurologic Sports Injury Center, Brigham and Women's Hospital; Chief of Neurosurgery Service, Chairman of the Department of Surgery, and Director of Sports Medicine at Emerson Hospital; Neurosurgical Consultant for the Boston Eagles football team; and Neurosurgical Consultant for the Boston Cannons professional soccer team. He has authored over 340 scientific publications, including 22 books on neurology and sports medicine, in addition to numerous book chapters, peer-reviewed papers, abstracts and free communications, and educational videos. Dr. Cantu's 2009 media appearances include providing testimony to Congress on the "NFL and Concussions," *CNN with Lou Dobbs* on the NFL Congressional Hearings, *CNN Saturday Morning,* and *60 Minutes,* as well as numerous radio programs for NPR and other networks.

Joseph M. Cummiskey attended medical school at University College Dublin from 1964 to 1970. He did his post-graduate training for 10 years in Northern California at Stanford University and the University of California, Davis, where he played and coached the Stanford University team for 3 years. His position then evolved into selection of the Northern Californian team and refereeing on the West coast. He returned to Ireland in 1985 to the then-new Blackrock Clinic. Dr. Cummiskey served as the Honorary Secretary of the Irish Sports Medicine Society from 1985–1988. He was Chief Medical Officer of the Olympic Council of Ireland from 1989–2000. A three year spell as secretary general of the Irish Sports Medicine association was followed by a 10 year spell as the chief medical officer of the Olympic Council of Ireland. He became a member of the International Olympic Committee Medical Commission in 2000. This was followed by joining the executive committee of the European Olympic Committee Medical Commission, the International Federation of Sports Medicine, and by being a member of the Medical and Scientific Commission of the European Federation of Sports Medicine Associations (EFSMA). In 2006 he entered the field of International Federations. He was soon on the Union of Cycling Medical Commission, the International Federation of Bobsleigh and Skeleton, and the International Cricket Council Medical Commussion. The most recent election saw him become the President of the European Federation of Sports Medicine Associations, the central body of the 41 countries of Europe.

Eduardo Henrique De Rose was born in Porto Alegre, Brazil, on August 8, 1942—the third son of parents emigrated from Italy. He married Regina Celi Fonticielha in 1967. They have two sons and one daughter. He holds dual citizenship with Brazil and Italy. He graduated with a degree in medicine from the State University of Sciences of Health in Porto Alegre, Brazil. Next he specialized in Sports Medicine at the University of Tours, in Tours, France. He earned a Masters degree in Sports Medicine in the University La Sapienza, in Rome, Italy. He earned an M.D. at the University of Cologne in the School of Physical Education in Cologne, Germany. He has been awarded the degree of Doctor "Honoris Causa" of the Pontifical Catholic University in Porto Alegre, Brazil. De Rose has been a strong member and elected board member of many boards and societies. He has been a member of the Medical Commission of the International Olympic Committee since 1984. He has been a member of the foundation board of the World Anti-Doping Agency since 1999. He has been President of the Medical Commission of the Association of National Olympic Committees since since 2003. He has been Honorary President of the International Federation of Sports Medicine since 2002. He has been President of the Medical Commission of the Pan American Sports Association since 1979. He has been Honorary President of the Pan American Confederation of Sports Medicine since 1991. He has been President of the Medical Commission of the South American Sports Organization since 1995. He has been a member of the Medical Commission of the Brazilian Olympic Committee (COB) since 1973. He has been President of the Anti-Doping Commission of the Ministry of Sports of the Brazilian Government since 2002. He has been Secretary General of the National Anti-Doping Organization of Brazil since 2008.

Avery Faigenbaum, Ed.D., is a full professor in the Department of Health and Exercise Science at The College of New Jersey. He serves on the editorial boards of several professional journals and is frequently quoted by national media. He was elected Vice President of the National Strength and Conditioning Association (NSCA) in 2005 and served on the Massachusetts Governor's Council on Fitness and Sports from 1998 to 2004. He was honored by the NSCA with the 1999 Junior Investigator of the Year Award, the 2000 State Director of the Year Award, and the 2003 *Strength and Conditioning Journal* Editorial Excellence Award. He is also a Fellow of the NSCA and American College of Sports Medicine. He is the author of numerous scholarly articles, as well as eight books for a general audience, including *Youth Strength Training* (2010) *Youth Fitness* (2001), and *Progressive Plyometrics for Kids* (2006). As an active researcher and practitioner in the field of pediatric exercise science, he continues to develop successful youth strength and conditioning and lecture at professional conferences worldwide

Walter R. Frontera is Dean of the Faculty of Medicine and Professor of Physical Medicine and Rehabilitation (PM&R) and Physiology at the University of Puerto Rico (UPR). Dr. Frontera completed his medical studies and a residency in PM&R at the University of Puerto Rico and received a doctoral degree in applied anatomy and physiology at Boston University. After completing his training, Dr. Frontera returned to the UPR School of Medicine and in 1993 he became the Chief of the Department of PM&R. In 1995 he spent a sabbatical year at the Karolinska Hospital in Stockholm, Sweden, in the Department of Clinical Neurophysiology studying the effects of aging. In 1996 he was recruited to Harvard Medical School to establish the Department of PM&R and was appointed the Earle P. and Ida S. Charlton Professor and Chairman of the Department of PM&R at Harvard Medical School and Spaulding Rehabilitation Hospital. His primary research interest is the study of the mechanisms underlying muscle atrophy and weakness in the elderly. His research has also included the study of skeletal muscle dysfunction in patients with neuromuscular diseases and muscle function with exercise training in patients with HIV. Dr. Frontera's research has been funded mainly by the National Institutes of Health. He has more than 200 scientific publications, including 76 peer-reviewed articles and 11 edited books. Currently, Dr. Frontera serves as the Editor-in-Chief of *The American Journal of PM&R*. He is a Regional Vice President of the International Society for PM&R; a charter member of the Kottke Society (an honorary society in rehabilitation medicine); and a fellow of the Association of Academic Physiatrists (AAP), the American Academy of PM&R, the American College of Sports Medicine, and other societies and organizations. In 2008 he was elected member of the Institute of Medicine of the National Academies (Washington, D.C.), and in 2009, member-at-large of the National Board of Medical Examiners. Dr. Frontera has presented more than 214 invited lectures in 52 countries and served as a grant reviewer and graduate research examiner for universities in Canada, South Africa, and Hong Kong. Active in international sports medicine, he is Past-President of the International Federation of Sports Medicine (FIMS). He has received several prestigious awards, including the AAP's Distinguished Academician Award in 2005 and Outstanding Service Award in 2010, the Best Scientific Research Paper (3 times) presented by the American Academy of PM&R, and the Harvard Foundation Award for his contributions to the field of PM&R. He is an honorary member of the Aragonese-Spanish Society of Sports Medicine, the Spanish Federation of Sports Medicine, the Malaysian Society of Sports and Exercise Medicine, the Chilean Society of PM&R, the Dominican Society of PM&R, the Euskalerria Society of Rehabilitation, and the Italian Society of PM&R.

Mary Lloyd Ireland is an orthopaedic surgeon and Associate Professor at the University of Kentucky, in Lexington, Kentucky. Dr. Ireland received her medical degree from the University of Tennessee. Her residency was at the University of California, Irvine, and her fellowships in Sports Medicine were at Children's Hospital Boston, Harvard University, Boston, Massachusetts, and Hughston Orthopaedic Clinic, Columbus, Georgia. She is a fellow of the American Academy of Orthopaedic Surgeons (AAOS) and American College of Sports Medicine. She is a member of the American Orthopaedic Society for Sports Medicine, the Ruth Jackson Orthopaedic Society, the American Orthopaedic Association, and an honorary member of the National Athletic Trainers Association. She served as Head Physician at the Olympic Sports Festival in Minneapolis, Minnesota in 1990 and as a Medical Staff Member at the Olympics in Barcelona, Spain in 1992. She has published numerous articles and chapters. She is co-editor of *The Female Athlete* (Saunders 2002) and editor of the AAOS *Instructional Course Lectures–Sports Medicine,* published (2005). She continues to pursue research on gender differences, and treatment and prevention of knee and shoulder injuries.

Mark Jenkins, the managing editor of the *Encyclopedia of Sports Medicine,* is the author of several books on sports health, including the *Sports Medicine Bible* and *SportsWise,* both of which he co-authored with Lyle Micheli. His feature articles have appeared in publications as wide-ranging as *The Wall Street Journal* and *Rolling Stone.* Mark is a former competitive athlete in rugby and squash, and he continues to play tennis and also bodysurf where he lives on the Island of Martha's Vineyard, Massachusetts. Mark is well-known locally and nationwide for his humorous National Public Radio (NPR) commentaries about island life.

Mininder S. Kocher is the Associate Director of the Division of Sports Medicine at Children's Hospital Boston and is an Associate Professor of Orthopaedic Surgery at Harvard Medical School. Dr. Kocher graduated Phi Beta Kappa from Dartmouth College where he was a member of the basketball and track and field teams. He graduated with honors from the Duke University School of Medicine. Clinically, Dr. Kocher's practice specializes in pediatric, adolescent, and adult sports medicine. He performs 600–700 operations annually and sees over 100 patients weekly in clinic. He is referred patients nationally and internationally. He lectures locally, regionally, nationally, and internationally. He is the head team physician for Babson College, Lasell College, Northeastern University, and the Boston Public School Sports Medicine Initiative. He is a physician for the Boston Ballet, the U.S. Ski Team, USA Track and Field, the Boston Marathon, and US Figure Skating. He has been elected to the elite sports medicine societies: The Herodicus Society and The ACL Study Group. In terms of research, Dr. Kocher is a renown orthopaedic health services researcher. Dr. Kocher has published over 100 peer-reviewed scientific articles, over 30 book chapters, and 3 textbooks. Administratively, Dr. Kocher is the Associate Director of the Division of Sports Medicine at Children's Hospital Boston. He is very involved with numerous professional organizations. He is a consultant reviewer for numerous medical journals and is a grant reviewer for numerous organizations.

John C. Richmond was a cum laude graduate of University of Pennsylvania in 1972 with a degree in Marine Biology. For his four years at University of Pennsylvania, he competed as a lightweight oarsman. John attended Tufts University School of Medicine, and was elected to Alpha Omega Alpha, Medical Honor Society in his junior year, and was President of that Society in his senior year. His residency training included two years of General Surgery at the Hospital of University of Pennsylvania, and three and half years of Orthopaedic Surgery at Tufts University Combined Orthopaedic Residency. Dr. Richmond is currently a Professor of Orthopaedic Surgery at Tufts University School of Medicine and an Adjunct Professor of Biochemical Engineering at Tufts University. He is the Chairman of the Department of Orthopedic Surgery at the New England Baptist Hospital, and practices at the Boston Sports and Shoulder Center in Chestnut Hill, MA. He was the Team Physician at Tufts University for 26 years and now serves as a consultant to the Athletic Department. His major focus in practice and research has been in advancing the treatment of the injured athlete, with projects ranging from basic science to long-term clinical outcomes. With various research teams at Tufts University he has received many awards, including the O'Donahue Clinical Research Award and the Cabaud Basic Science Research Award from the American Orthopaedic Society for Sports Medicine.

Martin P. Schwellnus holds an MBBCh (cum laude) from the University of the Witwatersrand, an MSc (Med), and a Doctor of Medicine degree from the University of Cape Town. He has been awarded fellowships from the American College of Sports Medicine and the International Sports Medicine Federation. Currently he is a full professor in Sports and Exercise Medicine at the Faculty of Health Sciences of the University of Cape Town, a Consultant Sports Physician at the Sports and Exercise Medicine Clinic at the Sports Science Institute of South Africa in Cape Town. He is also the Director of the FIFA (Fédération Internationale de Football Association) Medical Center of Excellence in Cape Town, and Director of one of only four International Olympic Committee (IOC) Research Centers in the world. His committee activities are extensive and include the following: Member of the IOC Medical Commission–Medical and Science group, Past Vice President of the International Sports Medicine Federation (FIMS), Vice President of the African Union of Sports Medicine (UAMS), and member of the CAF Medical Committee. He has over 300 publications in international sports medicine and national peer reviewed and non-peer reviewed scientific journals and has authored numerous chapters in sports medicine books. His current main research interests are the aetiology, prevention, diagnosis, and treatment of exercise associated muscle cramps (EAMC); the epidemiology of illness in athletes (including football players); the epidemiology, aetiology, diagnosis, and treatment of medical conditions in athletes; the biomechanics of overuse injuries in sports; genetics and sports injuries; and the epidemiology of injuries in sports.

Angela D. Smith, pediatric orthopaedic surgeon at the Children's Hospital of Philadelphia and its Sports Medicine and Performance Center, served as president of the American College of Sports Medicine, and received its Citation Award in 2006. She recently completed 2 terms as chair of the Education Commission of the International Federation of Sports Medicine, coordinating and teaching courses for health professionals worldwide. She serves on the advisory boards of the American Fitness Index and the Exercise Is Medicine initiative and is frequently quoted by national and international media. Her interests focus on injury prevention and rehabilitation, particularly for young athletes and for women pursuing sport or fitness activity. Through her clinical practice, public education efforts, and teaching in the University of Pennsylvania School of Landscape Architecture, she aims to improve each person's physical fitness, to improve their health, performance and self-esteem. She pursues her own lifelong passion for fitness and skating as a masters competitor, continuing to win Masters Senior medals at the U.S. Adult National Championships, recently becoming the U.S. National Showcase Masters Champion.

William D. Stanish is a professor of Surgery at Dalhousie University, within the Division of Orthopaedic Surgery. He is also Director of the Orthopaedic and Sport Medicine Clinic of Nova Scotia and has been since its inception in 1976. He received his medical degree at Dalhousie University, Halifax, Nova Scotia, Canada. Dr. Stanish was awarded the prestigious COA French Traveling Fellowship in 1978. He has held past presidencies in the Canadian Academy of Sport Medicine, the Orthopaedic Society of Nova Scotia, the Herodicus Sports Medicine Society, and has held executive positions on a number of provincial, national, and international societies. Dr. Stanish was Chief Medical Officer for the 1984 Olympics in Los Angeles as well as the 1988 Olympics in Seoul. Dr. Stanish is a past Deputy Editor of *The Journal of Bone and Joint Surgery,* and has held positions on the Editorial Board of the *American Journal of Sports Medicine, Techniques in Knee Surgery,* among many others. As a clinical scientist, he has fostered research in the areas of physiology of biomechanics of ligaments and tendons. His peer reviewed publicatoins by 2009 numbered 198. He has co-authored the highly regarded textbooks *The Oxford Textbook of Sports Medicine* and *Tendinitis: Its Etiology and Treatment*. Dr. Stanish has lectured worldwide and has been the recipient of many medals, honors, and awards.

Willem van Mechelen, MD, PhD, FACSM, FECSS (1952) is employed by the Vrije Universiteit Medical Centre in Amsterdam as a full professor of Occupational and Sports Medicine. In this capacity he is the head of the Department of Public and Occupational Health (120 fte), codirector of the EMGO+ Institute (350 fte), director of Research Centre Body@Work TNO VUmc and director of the Vrije Universiteit Medical Centre spin-off company Evalua Nederland BV. Willem van Mechelen is a board certified occupational physician, epidemiologist and human movement scientist. He is a editorial-board member of 8 peer-reviewed sports and exercise medicine journals, and associate editor of the *Clinical Journal of Sports Medicine* and of the *Journal of Physical Activity and Health*. He has (co-)authored more than 350 papers. He is a fellow of the American College of Sports Medicine and of the European College of Sports Sciences. In 2010 he received the American College of Sports Medicine citation award.

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Introduction

I have been a sports medicine doctor here at Harvard Medical School for almost 40 years, and I am convinced more than ever that this is one of the most exciting fields in the health care continuum.

The field of sports medicine is thriving in response to the demand for health care professionals to care for the growing number of men, women, and children who are participating in vigorous physical activity. Yes, it may be true that some of society's problems are due to inactivity among our citizenry, but paralleling this phenomenon has been an explosion in organized sports and recreational exercise.

At one time, there might have been a few privileged, upper-class ladies and gentlemen who could play golf, tennis, and polo, but now there are myriad sports and exercise opportunities open to all people, irrespective of age, class, race, or gender. And just as one kind of activity fades from the headlines (jogging and in-line skating), another one takes its place (extreme sports and Pilates).

With the growth in sports and exercise has come a concomitant increase in the number of related injuries. Often these are "acute" injuries, such as a sprained ankle while playing basketball or a skinned knee from falling off a mountain bike. There has also been a rise of so-called *overuse* injuries. Unlike acute injuries, which are the result of an accident, overuse injuries occur because athletes do too much of exactly what they're supposed to be doing, whether it's serving a tennis ball or jogging every evening. Trying to prevent overuse injuries has been one of the focal issues of sports medicine doctors like me.

Because there are so many segments of the population now engaging in sports and exercise, their sports medicine needs are also different. The young athlete, for instance, is not just a miniature adult and shouldn't be treated medically as such. Older athletes have their own special needs, as do active women.

Remember, too, that sports medicine is not just a specialty focusing on injuries. In addition to preventing, treating, and rehabilitating injuries, sports medicine deals with nutrition, conditioning, biomechanics, psychology, and more.

All this is to say that there are now many different people included in a sports medicine team compared with when I started in the field all those decades ago. Here, at the Division of Sports Medicine at Children's Hospital Boston at Harvard Medicine School, we have not just orthopedists but primary care physicians, athletic trainers, sports psychologists, nutritionists, podiatrists, and others.

With all the career opportunities available, it's no wonder that so many more people are developing an interest in sports medicine. For the same reason there are more athletes to be cared for, there are more people with an interest in sports and exercise who want to develop their interest into a career in health and medicine.

That is why I and so many of my peers got involved in sports medicine—we were athletes who became doctors, and we wanted to blend our occupation with our avocation. Now I see exponentially more people doing the same! Bravo to you, and I trust you will get the same enjoyment out of it as I and my contemporaries have.

The purpose of this encyclopedia is to provide an introduction to those very people who are developing an interest in sports medicine, as well as those who are presently working in the field. We have covered a marvelously broad spectrum of topics in what I trust is sufficient, but not overwhelming, detail.

As with any resource of this size and scope, a lot of planning went into its creation. How to decide which topics to cover? To a tree trunk called sports medicine, we attached branches of subspecialties such as nutrition and physical therapy and then twigs and leaves that represented topics and subtopics within those areas. At times, this seemed overwhelming given the scope of the field, but gradually and over time, we developed a headword list that was comprehensive but as short of redundancies as possible (though "better redundant than incomplete" was one of our mottos!).

Wherever it was feasible, we asked contributors to make their contributions as easy to understand for as many readers as possible. In many cases, this meant asking eminent scientists and academics to write at a level to which they are not necessarily accustomed, and I am grateful that so many were willing to make this necessary adjustment. I can speak from personal experience when I say that writing in this way after so many years of writing for scientific publications can be a challenge. Of course, sometimes our text will take a more scientific bent, but sometimes this is essential given the particular subject matter.

Above all, I am extremely pleased that we have contributions from so many preeminent experts in their fields. The list is long, and I run the risk of neglecting someone, so I will mention just a few names—Dr. Wilma Bergfeld (dermatology), Dr. Art Boland (history of sports medicine), Dr. Bob Cantu (catastrophic injuries), Dr. Eduardo De Rose (doping), Dr. Avery Faigenbaum (children's fitness), Dr. Steven Pribut (athletic footwear), and Dr. Jim Whiteside (team physician). The fact these men and women were willing to contribute entries says much about their interest in bringing their respective specialties to as wide an audience as possible.

I hope this will be your "go-to" guide when you have a question about sports medicine. Regardless of whether you use a hard copy of the *Encyclopedia of Sports Medicine* or the online version, I trust that, like generations of encyclopedia buffs before you, you will take pleasure in perusing this resource and searching randomly through it for the sheer pleasure of absorbing the knowledge you will find inside.

It has been an enormous pleasure to work with the many hundreds of health care professionals who contributed to this resource, as well as our august body of advisers. I hope the readers will take as much pleasure in the fruits of our labors.

Please enjoy and make use of this terrific and comprehensive resource, that it may educate you on one of the most fascinating areas of medical specialty—one I am pleased, proud, and honored to have worked in all these years.

Lyle J. Micheli, M.D.
Boston, Massachusetts

A Note on the Parts of the Encyclopedia

The *Encyclopedia of Sports Medicine* contains a number of invaluable features that combine to create a resource for all levels of need. First, the List of Entries enumerates the topics covered in the four volumes, a simple list in the same A-to-Z order in which they will appear in the encyclopedia. Next, a Reader's Guide organizes the entries into subject groups, so that the reader can see at a glance the natural clusters of related entries. These subject headings are as follows:

- Conditioning and Training
- Diagnosis and Treatment of Sports Injuries
- Diet and Nutrition
- Doping and Performance Enhancement
- Exercise Physiology, Biomechanics, and Kinesiology
- Injuries and Disorders
- Injury Prevention
- Medical Conditions Affecting Sports Participation
- Rehabilitation and Physical Therapy
- Special Populations
- Specialties and Occupations in Sports Medicine
- Sports Psychology
- Sports and Society
- Sports and Sports Medicine
- Sports Specific Injuries
- Women and Sports

Entries also contain two significant elements to guide the reader to more information inside and outside this encyclopedia. The *See also* section comprises cross-references to related entries within this project. The Further Readings are not a bibliography or references for every fact provided in the entry but a select list of readings and websites that the author chose above hundreds of others for first-stop research on the subject.

The *Encyclopedia of Sports Medicine* contains three items in addition to the alphabetical entries that combine to make it a unique didactic and reference source. The Glossary is a list of significant terms with their definitions, a critical study tool for students of all medicine programs and a memory aid for researchers and practitioners. Appendix A is an astounding compilation of descriptions and photographs of taping techniques. It covers the materials, procedures, and postassessment protocols for the most common of these applications. A related group of entries are the six on musculoskeletal tests, with a collection of more than 150 photographs of important methods for diagnosing injuries (Musculoskeletal Tests, Ankle; Musculoskeletal Tests, Elbow; Musculoskeletal Tests, Foot; Musculoskeletal Tests, Hand and Wrist; Musculoskeletal Tests, Hip; Musculoskeletal Tests, Knee; Musculoskeletal Tests, Shoulder; and Musculoskeletal Tests, Spine). Appendix B is an extensive list of organizations related to sports medicine.

As a final note, a little more information about the Further Readings, as they may be some of the most valuable items in this encyclopedia: References can be written in any number of styles, most developed by and named for a specific organization representing a large field of study. In this encyclopedia, the items in the Further Readings have, for the most part, been formatted in accordance with the American Medical Association (AMA) guidelines. However, the AMA is not the only style used within the medical profession. We have respected the diversity of our contributors and retained the journal abbreviations following PubMed guidelines. (PubMed, or MEDLINE, is the style used for references in the U.S. National Library of Medicine.) Abbreviations for journals indexed in MEDLINE can be viewed online at http://www.nlm.nih.gov/tsd/serials/lji.html. The following link is especially useful and provides a concise explanation of the U.S. National Library of Medicine's PubMed style. There are two standard formats in use—summary format, with article title first, and author-first summary format (as in the American Medical Association [AMA] style: see http://www.nlm.nih.gov/bsd/policy/cit_format.html).

A

Abdominal Injuries

Injuries to the abdomen as a result of participation in sports are uncommon. However, when such injuries do occur, they can be potentially life threatening. Therefore, to be sure that these injuries do not get overlooked, it is especially important to be aware of the types of abdominal injuries that may occur and how they may present.

Ten percent of all abdominal injuries result from sports-related trauma. Abdominal injuries occur most often in contact sports such as rugby, soccer, football, and wrestling. Noncontact sports, including horseback riding, downhill skiing, and waterskiing, can also result in abdominal injuries from high-speed deceleration mechanisms. Recreational activities such as bicycling can cause abdominal injuries from falls and from the impact of handlebars.

Anatomy

The abdominal cavity is separated from the chest cavity by the diaphragm. The position of the diaphragm varies with respiration. During expiration, the diaphragm may be as high as the fourth anterior rib. This is important because the abdominal contents may be raised well into the chest and, therefore, may be exposed to chest wall trauma.

The peritoneal cavity contains solid organs including the spleen, liver, and pancreas and hollow, viscous organs such as the stomach and the small and large intestines. Other structures that may be injured include the lower ribs, the bladder, retroperitoneal organs (e.g., the kidneys) and spaces, the abdominal wall muscles, and blood vessels.

Evaluation of Injury

Abdominal injuries may result in serious bleeding and shock. If an athlete on the field appears to be in shock, assessment of airway, breathing, and circulation should be quickly performed by qualified personnel. Paramedics should be called to transport the athlete to hospital. Intravenous access should be obtained by trained health care personnel (doctor, nurse, or paramedic) in two separate sites with large-bore cannulas, and the patient should receive rapid infusion of normal saline solution en route to a trauma center.

Details of Injury

Abdominal injuries in sports are usually caused by a rapid deceleration or high-energy impact. Pain may occur immediately or develop more insidiously. The location, quality, and severity of pain can help determine what injury has occurred. Pain may be aggravated by activities such as walking or coughing. Athletes with abdominal injuries may also have other symptoms, such as back pain or blood in the urine.

Physical Findings

It is important to monitor the heart rate and blood pressure of any athlete who has sustained an abdominal injury. If the blood pressure is low and the heart rate is high, the athlete may be in shock. There may be bruising of the abdomen, as well as bloating, abrasions, or lacerations at the site of impact. Palpating the abdomen can determine the area of greatest tenderness. Contusions or bruising of the abdominal wall muscles can be difficult to distinguish from an underlying abdominal injury. Tenderness with contusions is usually well localized, and pain may be elicited through contraction of the affected muscle. With abdominal injuries, however, tenderness with palpation may be more diffuse. Up to 50% of athletes with significant abdominal injury do not initially have any tenderness to palpation of their abdomen. If a serious abdominal injury is suspected because of the type of trauma, the injured athlete should be reexamined by a doctor over several hours.

Injuries to solid abdominal organs, such as the liver or spleen, cause bleeding, resulting in irritation and pain in the abdomen. Pain can initially be mild, with no palpable tenderness. Injuries to hollow organs, such as the bowel, result in peritonitis, or infection of the abdomen, which can cause severe pain. The pain is initially localized to the site of injury, but as the injury progresses, peritoneal signs, such as referred tenderness and loss of bowel sounds, develop. Injuries to organs behind the peritoneal cavity, such as the kidneys, may not cause peritoneal signs, particularly if trauma is minor. Blood in the urine may be the only sign of an injury to the kidneys.

Traumatic injuries to the abdomen may result in other injuries that may not be immediately obvious. For instance, injuries to the abdomen may also cause a chest injury, such as a pneumothorax (air in the chest outside the lungs). Conversely, trauma to the lower chest wall, such as the ribs, may result in injury to abdominal organs, such as the liver or spleen.

Investigations

An athlete who has sustained an abdominal injury may be bleeding internally. Blood loss can be determined by measuring the hemoglobin in the athlete's blood. A drop in the hemoglobin suggests significant blood loss. If a serious abdominal injury is suspected, a CT scan may show the exact nature of the injury. The combination of repeated abdominal examinations and CT scan usually detects any significant abdominal injury. CT scan alone can potentially miss clinically significant abdominal injuries.

Types of abdominal injury:

- Splenic lacerations, contusions
- Splenomegaly, splenic rupture (caused by the Epstein-Barr virus)
- Liver lacerations, contusions
- Kidney injury
- Pancreas injuries
- Bowel injuries
- Sportsman's hernia
- Muscle contusions, sprains

Prevention of Injury

Although abdominal injuries are uncommon, certain injuries may be preventable. Appropriate safety equipment should be worn for any particular sport or recreational activity. Attention to proper sports technique can minimize the incidence of overuse injuries, such as muscle strains. Conditioning is also very important. Appropriate core strength will help maximize protection in contact sports, as well as minimize overuse injuries in noncontact sports.

Return to Sports

Sideline decisions regarding allowing an athlete to return to play following an abdominal injury should be based on pain severity and resolution. Heart rate and blood pressure should be normal, and there should be no peritoneal signs or significant tenderness to palpation on abdominal exam. In addition, athletes should be able to exercise without increasing pain.

Specific guidelines vary with the severity of injury. Solid-organ contusions require a normal CT scan 2 to 3 weeks before an athlete can return to practice. A prolonged period of healing is necessary for lacerations or hematomas to solid organs. If the injury is severe enough to require organ removal, full healing should take about 6 to 24 weeks. Strenuous activity following organ removal should be delayed for 6 to 8 weeks, and participation in contact sports should be delayed for 12 to

24 weeks, depending on the specific advice of the surgeon performing the surgery.

Laura Purcell

See also Bowel Injury; Hepatic Injury; Pancreatic Injury; Trunk Injuries

Further Readings

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Abrasions and Lacerations

Abrasions and lacerations are among the most common skin injuries seen in athletes.

Abrasions

An *abrasion* is the result of damage to the epidermis (superficial layers) of the skin resulting in superficial erosions or ulcerations. Abrasions are caused by friction or pressure forces directed against the skin. They commonly occur while skateboarding, cycling, or inline skating. Prevention includes wearing protective clothing and gear.

Cleaning of a superficial wound can be done with the use of a sterile saline solution and application of petrolatum or topical antibiotic ointment. If the abrasion is deeper than the epidermis, the wound should be evaluated for foreign body material. Cleaning of the wound should be more extensive to prevent infection and permanent discoloration of the skin from the foreign debris. Wound debridement is important to reduce the risk of infection. Cleaning of wounds with high-pressure irrigation is more effective than cleansing with low-pressure irrigation. Irrigation with an 18- or 19-gauge needle attached to a 20- or 30-milliliter (ml) syringe provides adequate pressure of 5 to 8 pounds per square inch (psi), or 35 to 55 kilopascals (kPa), for debridement. Pain can be alleviated with topical or local anesthesia. Management of erosions or ulcerations may include a hydrocolloid dressing to aid in wound healing. Hydrocolloid dressings aid in wound healing by maintaining a moist environment. They do not require a secondary dressing, are fibrinolytic, are absorbent, increase angiogenesis, and act as bacterial and physical barriers. Infected wounds should be treated with antibiotics such as cephalexin 500 milligrams (mg) twice daily for 10 to 14 days or dicloxacillin 500 mg three times a day for 10 to 14 days.

An athlete may typically return to competition after proper repair and bandaging of the abrasion (see Figure 1, p. 4).

Lacerations

A *laceration* is the tearing of the skin resulting in an irregular wound. Lacerations are often caused by impact injury from a blunt object or force. They commonly occur in contact sports and are the most common type of sports-related facial injury. Lacerations may occur after a fall, commonly occurring on the elbow, knee, or eyebrows. Tissue injury is typically minimal, and infections are usually low. However, the laceration may extend through the full thickness of the skin into the subcutaneous tissue. When the injury occurs over a bony prominence, such as the brow, cheek, chin, or teeth, a jagged tear in the skin occurs, with variable skin ischemia and necrosis.

Wound repair is an important process in restoring the skin to its pre-injury state. For acute wounds, the repair process progresses from coagulation to inflammation, proliferation, cell migration, and tissue modeling. After an acute injury, coagulation and inflammation begin immediately. Clot formation begins with the release of blood cells and blood-born elements, such as platelets, from the disrupted blood vessels. Through the intrinsic and extrinsic pathways, platelets direct the clotting of the wound and release chemotactic factors that attract other platelets, leukocytes, and fibroblasts to the wound. Inflammatory white cells aid in the debridement of necrotic material and bacteria. Growth factors are activated because of the injured environment secondary to hypoxia, proteases, and low pH. A fibrin plug, consisting of platelets, is embedded within a meshwork of fibrin,

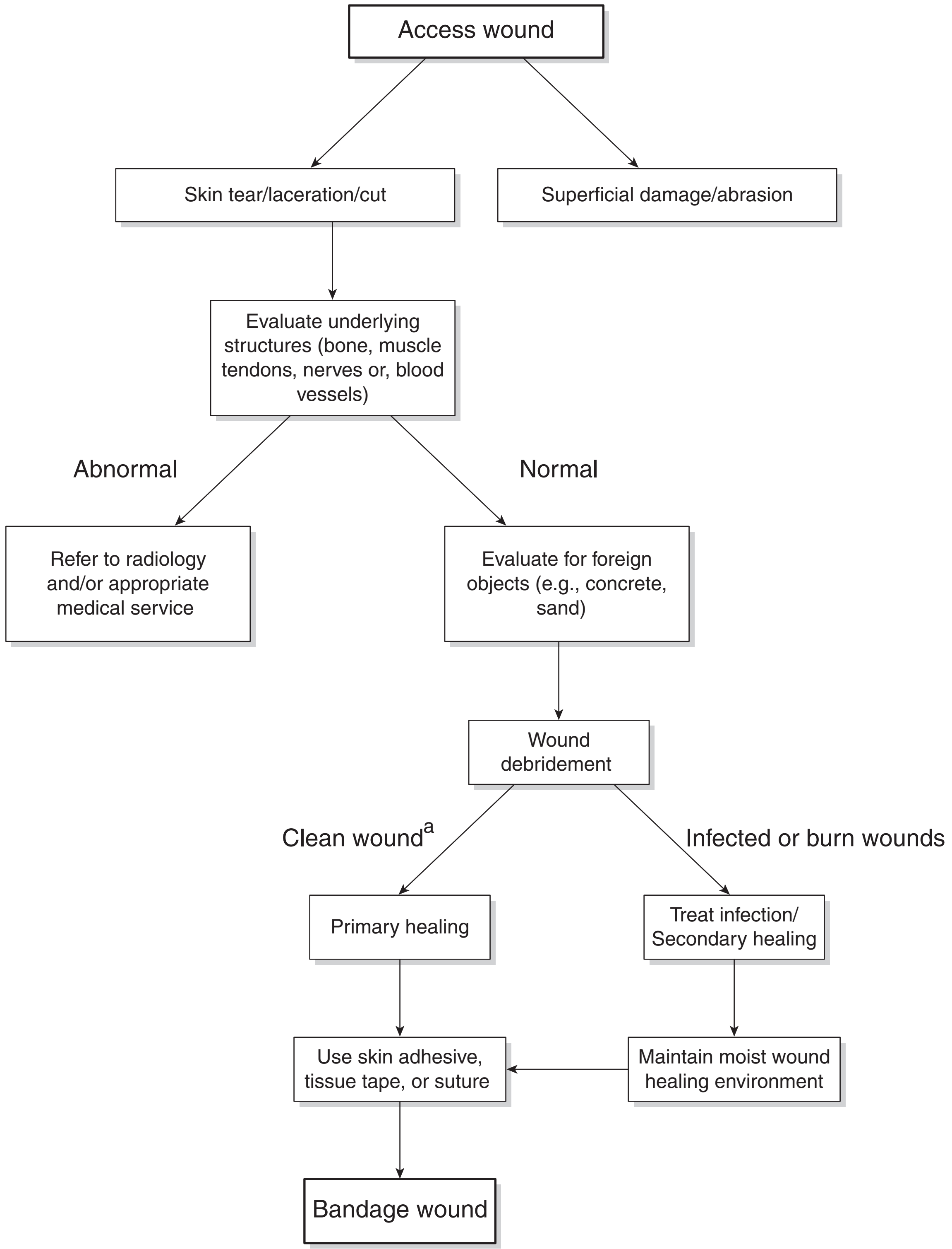

Figure 1 Treatment of Abrasions and Lacerations

Note: [a]Superficial wounds/abrasions can be treated with skin adhesive or tissue tape, or maintained with a moist wound-healing environment after wound debridement.

fibronectin, vitronectin, and thrombospondin. This provides a temporary cover for protecting the wound. When cross-linking of fibrin does not occur, the function, and likely migration, of keratinocytes is impaired. Keratinocytes proliferate within the first hours after the injury is sustained. Within 24 to 48 hours, monocytes are present in the wound and become macrophages. These are important for killing bacteria, scavenging tissue debris, and phagocytosis. The macrophages attract fibroblasts, which create a collagen network of fibers. During this stage of proliferation, granulation occurs. Fibroblasts become myofibroblasts, which help contract the wound and assist with remodeling. Epitheliazation results in epithelial cells migrating to the epidermis around the wound and growing over the granulation tissue.

An individual's state of health can also impede the wound-healing process. Deficiency of vitamin C or zinc can impair wound healing. Vitamin A is important in epithelialization as well as collagen production and degradation. However, too much vitamin A is considered toxic. The estimated toxic dose is 25,000 international units/kilogram (IU/kg). Iron deficiency may delay wound healing as iron is a cofactor in collagen synthesis. Underlying endocrine disorders, such as diabetes or corticosteroid use, can also slow the healing process. Knowing the athlete's medical history can be critical to ensuring a rapid healing process.

Appropriate treatment of lacerations is important to decrease the risk of excessive scar formation and displeasing cosmetic results. Due to the rich blood supply of the face, lacerations in this location may bleed significantly. Control of hemostasis is the first step in the management of lacerations. Direct continuous manual pressure to the area of injury with sterile gauze is helpful for achieving hemostasis. After hemostasis is achieved, exploration of the wound should be completed to determine the severity and extent of involvement of bone, muscle, tendons, nerves, or blood vessels. Fractures of any underlying bony prominences should be excluded through initial palpation, with referral to radiology as needed. Residue, such as concrete or sand, from the foreign object that caused the injury may be left within the wound. Wound debridement is important to reduce the risk of infection and later reaction to the foreign body(ies). The wound should be irrigated with sterile saline solution. Cleansing of wounds with high-pressure irrigation is more effective than cleansing with low-pressure irrigation. Irrigation with an 18- or 19-gauge needle attached to a 20- or 30-ml syringe provides adequate pressure of 5 to 8 psi (35 to 55 kPa) for debridement.

The type of wound closure used depends on the wound. Primary healing occurs when the laceration is clean and is closed with skin adhesives, tissue tapes (Steri-Strips), or sutures. Secondary healing occurs when the wound is left open to heal by the formation of granulation tissue, contraction, and epithelialization. Typically infected and burn wounds heal through secondary healing. Delayed primary closure is often used for lacerations that are not considered to be clean enough for primary closure. The wound is left open to heal for 5 to 10 days in a moist wound-healing environment, and then it is sutured closed. A moist wound-healing environment includes the use of dressings that retain moisture to improve pain control, effect painless autolytic debridement, provide physical and bacterial barriers, and promote the formation of granulation tissue. Examples of such wound dressings are hydrogels, alginates, hydrocolloids, foams, and films. Hydrocolloids are favorable as they do not require a secondary dressing, are fibrinolytic, are absorbent, increase angiogenesis, and are bacterial and physical barriers. Delayed primary closure decreases the risk of infection through achieving bacterial balance, and granulation tissue formation creates an optimal environment for the wound's oxygen requirements.

Temporary closure of superficial and small lacerations can be done with tissue tapes (Steri-Strips) or butterfly bandages, which aids the wound in achieving hemostasis and allows the athlete to resume playing. These are appropriate if the wound does not exhibit great tension. To ensure that the strips or bandages are secure, a liquid adhesive, such as compound benzoin tincture or 2-octylcyanoacrylate, can be applied. The depth and location of the laceration may also determine the type of treatment rendered. Full-thickness lacerations may require closure with sutures. Deep, absorbable sutures may be needed for better approximation of the edges. Nonabsorbable sutures should be used for skin closure, which should optimally be completed in 8 to 12 hours. Burst or jagged laceration edges should be trimmed with a sterile scalpel to create a more linear and smooth edge, which is better for approximation of the wound for closure with sutures. The sutures are typically removed in 5 to 7 days if they are located on the face and ears, 3 to 5 days for eyelid sutures, 7 days for neck sutures, and 7 to 14 days for scalp sutures. Sutures on the trunk and extremities should be left in place for 10 to 14 days and occasionally longer to reduce the risk of wound dehiscence if the closure is under extreme tension. If the wound is easily approximated with subcutaneous sutures, then they can be removed in 7 to 14 days. After removal, the addition of tissue tapes may be needed to add strength to the healing wound.

With ear lacerations, it is important to completely cover the exposed cartilage and evacuate any blood to prevent a hematoma. Hematoma formation can result in pressure necrosis of the cartilage, loss of stability and shape of the ear, and infection. Hematomas should be drained within 72 hours with the use of an 18-gauge needle and syringe or through incision and drainage. Simple lacerations can be repaired with nonabsorbable, monofilament sutures. When cartilage is exposed, suturing the skin over the cartilage should be sufficient as the cartilage itself does not need sutures. If the cartilage must be debrided, only up to 5 millimeters can be removed to prevent ear deformity.

Antibiotics are often not needed for the treatment of simple lacerations. A wound that has remained open for several hours or is heavily contaminated may require a 7- to 10-day course of antibiotics. Lacerations from human bites may also require antibiotics, and tetanus prophylaxis guidelines should be followed.

The athlete may typically return to competition after proper repair and bandaging of the laceration. Bandaging can be completed with a sterile, nonadherent dressing. The location of the laceration, its severity, and the potential for recurrence of the injury should be taken into consideration. The wound will gain in strength 2 to 3 weeks after the repair, with a peak tensile strength at 2 months. The final tensile strength is about 70% to 80% of the pre-injured skin 1 to 2 years later. Full-thickness wounds are associated with delayed healing and more scarring. If wound dehiscence or infection is of concern, the patient should follow up within 48 hours for a wound check.

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See also Ear Injuries; Friction Injuries to the Skin; Skin Conditions in Wrestlers

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Accessory Navicular

The *accessory navicular* is an extra bone in the foot that can become painful. Not every person with an accessory navicular will have pain. However, when it is causing pain, it can be difficult to treat and may necessitate surgical removal.

Anatomy

The navicular is one of the tarsal bones in the foot. It is located on the inside, or medial aspect, of the foot, at the arch. The accessory navicular is an ossicle, or extra bone. Some people are born with this ossicle.

The posterior tibialis muscle tendon attaches to the navicular bone. This muscle *inverts* (turns in) and *plantarflexes* (points toward the toes) the ankle. This muscle also helps stabilize the medial arch of the foot. The tendon will insert on the accessory navicular, which may cause pain and muscular dysfunction, including loss of the medial arch (flat foot).

The accessory navicular is present at birth, but it is then a soft cartilage. It will begin to ossify (from into a bone) around 9 to 11 years of age. It is usually connected to the navicular with a fibrous union. Some physicians believe that approximately 50% will fuse to the navicular in late adolescence, but this has not been definitively established.

Causes

About 10% of people have an accessory navicular. However, not that many people have symptoms related to it. If the ossicle is large, it can cause a large bump on the medial aspect of the foot. This bump will rub against shoes and can become very painful.

Also, injuries of the fibrous union between the accessory navicular and navicular bone can cause pain. These injuries may destabilize the ossicle, resulting in abnormal motion. This is analogous to a fracture. However, the fibrous tissue connecting the two pieces tends to heal poorly, resulting in continued pain. The attachment of the posterior tibialis muscle causes a constant pull and stress on the ossicle.

If a large portion of the posterior tibialis tendon attaches to the accessory navicular, it can disturb the supportive function of the muscle. This leads to flat foot and an even more prominent accessory navicular bone.

Clinical Evaluation

Many patients will present in childhood with a symptomatic accessory navicular. As the accessory navicular begins to ossify, it may become more symptomatic. An accessory navicular that has no symptoms is not problematic, and treatment should not be initiated unless it becomes symptomatic.

History

Many patients will present in early adolescence with a painful bump on the inside of their foot. If they are very athletic, the pain will worsen during and after activity. Even walking can be painful, and the pain can eventually become a constant discomfort. It will generally improve with rest. If the bump is larger, the patients frequently complain of pain when it rubs against their shoes or if something hits the bump.

The patient and family often have concerns about flat foot, which is commonly associated with the accessory navicular.

Physical Exam

Patients will usually have a flexible (nonrigid) flat foot. They will have a bony prominence over the medial aspect of the foot at the arch. This prominence is painful to palpation. Resistance testing of the posterior tibialis muscle is often painful as well.

Diagnostic Imaging

X-ray films should be obtained. Comparison views of the other foot may be helpful. If the patient is young, the ossicle may not have ossified yet, so it may not be seen on X-ray. The accessory navicular will appear as a distinct ossicle proximal and medial to the navicular bone.

In a patient with an accessory navicular that is not clearly the cause of pain, a bone scan or magnetic resonance imaging (MRI) may help pinpoint the diagnosis.

Classification

Type I: A small ossicle located entirely within the posterior tibialis tendon and separate from the navicular bone

Type II: The classic accessory navicular, which has a fibrous connection to the navicular and also has a portion of the posterior tibialis tendon attached

Type III: A cornuate navicular, which represents a bony fusion of the accessory navicular to the navicular, resulting in a bony prominence on the medial foot.

Treatment

Nonoperative

Accessory navicular treatment is initially nonoperative. If the pain is significant, the patient may

Accessory navicular

Source: Photo courtesy of Kevin D. Walter, M.D., Children's Hospital of Wisconsin.

benefit from 4 to 6 weeks with the foot in a fracture boot or a cast. This should be followed by ankle strengthening and range-of-motion exercises designed to return the athlete to full speed of movement without pain. Crutches may be helpful early, but the patient can bear weight as tolerated.

When the pain is less severe, activity modification is the primary treatment. The pain can be decreased by keeping the athlete from performing activities that cause pain (usually weight-bearing activity). During this time, the athlete can try ice and over-the-counter medications to help control the pain. The athlete should wear good, supportive shoes and consider an arch support or orthotic to help stabilize the arch, which may reduce the pull of the posterior tibialis muscle. Donut padding around the painful prominence may be helpful. Again, exercises designed to improve overall ankle function through increasing strength, flexibility, and balance should be instituted when it is possible to do them without significant pain. It may take the athlete 4 to 6 weeks to return to full activity without symptoms.

If the pain subsides and the athlete can return to full activity, there is no need for any further treatment. The patient should return if symptoms return at a later date. Athletes who do not get full relief from activity modification may then need casting. If the symptoms are not responsive to the full spectrum of nonoperative care, the patient should be seen by an orthopedic surgeon.

Operative

The most common operation is the Kidner procedure. This involves removal of the accessory navicular and repositioning of the posterior tibialis tendon onto the navicular bone. This requires significant postoperative immobilization because the tendon has been manipulated. This procedure may restore the arch of the foot because of the improvement in the position of the posterior tibialis tendon.

Some surgeons will remove the ossicle, but there are concerns that this may disrupt the stability of the foot and result in poor function of the posterior tibialis muscle, causing it to tire easily.

However, there is a recently developed technique that allows surgeons to remove the ossicle and strengthen the attachment of the posterior tibialis tendon without complete detachment and reattachment. This allows for a quicker return to activity without prolonged immobilization.

After surgery and the required immobilization, the athlete will frequently need physical therapy to help strengthen the ankle to return it to normal function. Orthotic use may be helpful in the postoperative patient who still has flat feet.

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See also Ankle Injuries; Arch Pain; Musculoskeletal Tests, Foot; Orthopedist in Sports Medicine, Role of; Orthotics; Posterior Tibial Tendinitis

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Achilles Bursitis

Posterior heel pain in the athlete may be due to any of a number of causes. Possible diagnoses include tendinitis, retrocalcaneal bursitis, or Achilles bursitis, to name a few. In this entry, *Achilles bursitis*—specifically, bursitis of the retro-Achilles or superficial bursa—is examined in detail, including its causes, symptoms, and treatments.

Anatomy

The Achilles tendon is composed of fibers originating in the muscles of the calf (the gastrocnemius and soleus). The tendon is palpable from the lower one third of the calf down to the calcaneus or heel bone. In the region where the Achilles tendon attaches to the calcaneus, there are two bursae—the retro-Achilles bursa and the retrocalcaneal bursa—that work together to reduce friction by the Achilles tendon. The *retro-Achilles*, *calcaneal*, or *superficial bursa* lies between the insertion of the Achilles tendon and the overlying skin. In contrast, the retrocalcaneal bursa—which is addressed elsewhere—lies between the anterior surfaces of the Achilles and the calcaneal bone itself.

Epidemiology/Etiology

The retro-Achilles bursa can become inflamed as a result of damage to the Achilles tendon or excessive external (shoe) pressure on the area. This bursa is the one that is most commonly enlarged. This enlargement is attributable to overly tight running shoes and, historically, high heels—leading to its common name, "pump bump." Achilles bursitis is most common in runners but can occur in any athlete who wears ill-fitting shoes.

Signs and Symptoms

Patients complain of pain over the posterior heel. Redness, swelling, and significant pain can be localized to the bursa just under the skin overlying the Achilles. Usually, this is just below the position of the shoe's heel counter. This may be thickened or enlarged.

Physical Exam

The area, if thickened, may be palpable. To localize the retro-Achilles bursa, the examiner should lift the skin posterior to the Achilles—the bursa lies just under the fingers. In contrast, the retrocalcaneal bursa is localized by pinching the soft tissue anterior to the tendon. In addition to pain, the patient will also have decreased passive dorsiflexion, or flexion at the ankle.

Diagnostics

Physical exam is usually sufficient for diagnosis. If pain is recalcitrant to treatment, X-ray should be considered to rule out a Haglund deformity. Another disorder in the differential diagnosis can be calcaneal stress fracture, which will require further imaging to diagnose.

Treatment

Because ill-fitting shoes commonly contribute to this problem, careful attention to footwear is the first place to start. Alterations can be made by changing shoes outright or adding padding to the shoe being worn. Ice massage is also helpful at times. As with any superficial bursitis, the physician can aspirate the bursa and give a small steroid injection—though this should be done with caution considering the proximity to the Achilles tendon and the attendant concern for Achilles rupture.

If this is a chronic problem, consideration should be given that over time, small bony flakes or avulsions can become hardened and thickened, creating a bony prominence in longtime runners. Treatment for this also includes adding padding or changing shoes. Heel lifts or orthotics may also be helpful in this situation. Surgery is rarely indicated due to proximity to the Achilles tendon.

Prevention

Catching this problem early facilitates successful treatment. Athletes should always be aware when changing shoes that different pressure patterns on the posterior foot can cause inflammation. If this is noticed, increasing padding or changing shoes is the best thing to do.

Jacklyn D. Kiefer and Stephen M. Simons

See also Achilles Tendinitis; Retrocalcaneal Bursitis

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Achilles Tendinitis

Since humans began walking on two legs, the Achilles tendon likely has been a common site of injury. Achilles injury is most common among professional and recreational athletes of all ages, and the Achilles is the most frequently injured tendon in the ankle. *Achilles tendinitis* is, basically, pain in and around the Achilles (triceps surae) tendon. Terminology varies widely, and terms such as *tendinopathy, tendinitis, partial rupture, paratenonitis, tenosynovitis,* and *achillodynia* have all been used to describe this entity. For the purpose of this review, this terminology will be consolidated under the term *tendinitis*. Achilles tendinitis is a multifactorial problem. Everything from anatomy to footwear can play a role in its development. In this entry, these causes will be investigated, and general treatment options will be addressed.

Anatomy

The Achilles tendon is composed of the conjoined tendon of the calf muscles—the gastrocnemius and the soleus—and is the largest tendon in the body. These muscles contribute to the ability to plantarflex (point the toes) and give strength to this motion, as well as absorbing the weight of the body in ambulation; in short, they give the primary force needed to walk, run, and jump. The most distal portion of the tendon has poor blood supply; this is especially true in the area 2 to 6 centimeters (cm) above the calcaneus, or heel bone.

Epidemiology

Incidence of Achilles tendinitis is highest among those who participate in middle- to long-distance running, track-and-field events, tennis, volleyball, and soccer. Men seem to be more prone to developing Achilles tendinitis than women, and it affects the older athlete more often than the younger athlete. The athlete who is reentering training after a period of inactivity is also at risk.

Etiology

Achilles tendinitis is largely multifactorial in causation. In competitive athletes, most of these injuries are attributable to a chronic, repetitive overload of the tendon unit. In recreational—including "weekend warrior"—athletes, it is usually due to acute overloading. In this particular problem, the most common training error is increasing activity too quickly. This usually includes increasing mileage rapidly, increased interval training, or increased hill running. Previous in\juries also play a role, both to the Achilles itself as well as to the surrounding tissues (as in plantar fasciitis). In the professional athlete, chronic overuse that eventually results in tendon pain and poor remodeling is usually blamed.

Anatomic malalignments can also play a role. *Pes planus* (flat foot) and *pes cavus* (high-arched foot) have both been suggested as contributing factors to Achilles injuries. These anatomic factors place increased stress on the Achilles tendon as a stabilizer of the ankle. Another factor is decreased flexibility. Tightened muscles in the calf (particularly the gastrocnemius-soleus complex) have been suggested to increase the likelihood of tendinitis.

Improper footwear has also been implicated. Each individual foot is unique, and with a proper shoe the impact to the foot as well as the amount of pronation allowed can be controlled. Shoes with soft, unstable casing are not firm enough to resist compression during foot pronation. Soft heel counters also do not hold the foot in the right position, though a too rigid shoe is equally detrimental.

Signs and Symptoms

Individuals will likely present with decreased gastrocnemius flexibility, pain, tenderness, and swelling at the site. Crepitus may also be present. Pain is worse with active plantarflexion (pointing of toes)—especially when weight bearing. This pain is generally worse on arising from sleep. The activities sufferers dread the most include walking up hills or down stairs. In addition, running and jumping may become impossible.

Physical Exam

Tenderness is noted along the Achilles. Most commonly, a thickened, tender nodule is found on the proximal one third of the tendon. Pain will occur with single-legged heel raise of the affected extremity. Rupture of the Achilles should be ruled out, though this complaint is usually of a more acute nature—in contrast to the more insidious onset of tendinitis. This can be tested by doing the Thompson Squeeze Test. The patient should lie prone on the exam table. The calf of the leg is squeezed; if there is plantarflexion of the foot, the tendon is intact; however, if it is markedly decreased or absent, it indicates rupture.

Diagnostics

Though the diagnosis of Achilles tendinitis is mostly clinical, imaging modalities may be used. If thickening of the Achilles is observed, some physicians may include X-ray evaluation in the workup. Musculoskeletal diagnostic ultrasound is also an option. This can be especially helpful as it can be performed in the physician's office, and the patient's pain can be a guide. Generally, a heterogeneous configuration of tendon fibers suggests tendinitis, and a homogeneous configuration suggests a normal tendon. Increased blood flow to an area is also an indicator of injury. If the course is prolonged or the patient fails to respond to conservative therapy (usually after 6 months), further imaging may be necessary. This imaging would include magnetic resonance imaging (MRI).

Treatment

As with most musculoskeletal injuries, the earlier the treatment, the better the outcome. Initial treatment should include rest, ice, and the use of acetaminophen or nonsteroidal anti-inflammatory agents such as ibuprofen or naproxyn. Stretching before exercise is encouraged, in addition to decreasing mileage, avoiding banked roads and hills, and changing footwear.

The amount and duration of rest are not well defined. If the pain occurs only after activity, one guideline states that training should be decreased by 25%. If the pain occurs with activity but does not restrict performance, training should be decreased by 50%. If the pain restricts performance, then the athlete should discontinue specific sports training, but substitute exercise (e.g., swimming) would be encouraged. Rest should continue 7 to 10 days after the symptoms have subsided. Subsequently, a gradual return to activity is encouraged.

Appropriate shoes should have a flexible sole and molded heel pad. If the athlete is a pronator (has a flat foot), orthotic correction is recommended. Heel lifts have also been shown to relieve the stress to the Achilles tendon; if used, this should be about 0.5 inch (1.3 cm) high. If this approach is used, aggressive Achilles stretching should also be performed since the lift shortens the Achilles tendon. These lifts are typically used for several weeks.

In more severe cases, a walking boot may be considered for temporary unloading. *Under no circumstances should steroid injections be used.* They have been shown to compromise the vascular system as well as contribute to weakening and possible necrosis of the tendon.

Physical therapy should include primarily stretching and eccentric strengthening exercises to mobilize the tissue. These eccentric exercises can significantly improve symptoms in 3 to 6 months. Ultrasound has also been reported to have some success.

Surgery has been shown to have a limited role in the correction of Achilles tendinitis. This is primarily because the area most commonly affected has poor blood supply, so surgical healing is difficult. If complete tendon rupture occurs or the injury is particularly recalcitrant to conservative measures, a surgeon should be consulted. However, most experts recommend that a full course of conservative rehabilitation and therapy be completed before surgical intervention is considered.

Prevention

Perhaps the best treatment of Achilles tendinitis is prevention. This can be achieved by knowing and avoiding the predisposing factors. Resistance training should be done to increase the strength of the calf and other lower extremity muscles. A stretching program can also help maintain or achieve greater flexibility. Correcting structural defects of the foot with orthotics can also decrease the chance of future Achilles injury. Also, understanding the proper footwear, training surfaces, and training programs to use helps decrease the extrinsic risks of developing Achilles tendinitis. As part of these precautions, warm-ups should be included in any training program, and if one is starting to train for a running event or starting exercise after a sedentary period, the first week is the most likely to result in injury. Having "easy days" interspersed with hard training also allows the body time to recover. Overall, one can see that this multifactorial problem can only be treated and prevented in an equally multifactorial way.

Jacklyn D. Kiefer and Stephen M. Simons

See also Achilles Bursitis; Achilles Tendon Rupture; Flat Feet (Pes Planus); Retrocalcaneal Bursitis

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Achilles Tendon Rupture

The Achilles tendon is extremely important in any activity in sports that involves foot flexion. The tendon has its origin at the muscle-tendon junction of the gastrocnemius muscle and inserts on the posterior calcaneus bone of the ankle. The function of the tendon is to flex the foot. It is continually under tension to be able to carry out this function.

Pathophysiology and History\

Achilles tendon rupture or tear generally occurs in the third to fifth decade of life. This is a time when the tendon is aging and not as pliable as in earlier life, thus making it more prone to injury or damage due to continued microtrauma. Rupture usually happens to an athlete who is not properly warmed up or stretched or in someone who has a naturally tight tendon in sports involving jumping, such as volleyball, basketball, or dance. When the tendon is torn, the patient often reports hearing a "pop" and describes a tearing sensation in the lower leg. If looking at the patient from behind, there is often a gap seen between where the Achilles tendon should be and the edge of the calcaneus bone. The area then frequently becomes swollen and bruised. Often, patients report that they cannot walk correctly as they cannot adequately push off with the affected foot.

Physical Examination

A patient with Achilles tendon rupture cannot walk on his or her own. Crutches are often required. Movement is affected, as the patient cannot properly plantarflex or flex the affected foot. Strength is also diminished on the affected side. The doctor is often able to feel a missing section of tendon as he or she follows it from the calcaneus to the gastrocnemius. The examiner also can feel swelling and sometimes, if enough time has elapsed, see bruising. The most important physical examination test to be performed is the *Thompson Test*. The patient's calf is squeezed. If the foot does not flex at all after squeezing, then the tendon has completely ruptured. Plain X-rays can often show the missing tendon, but the best test to see a complete

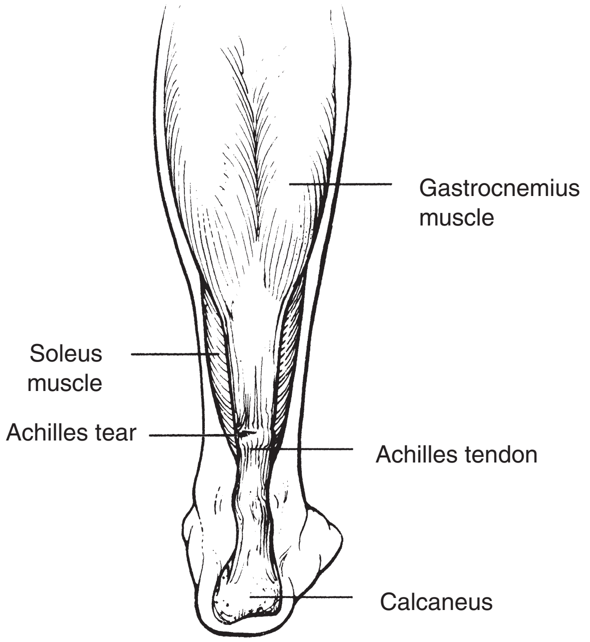

Figure 1 The Calf Muscles and Achilles Tendon Showing Achilles Tear

tendon rupture is magnetic resonance imaging (MRI; see Figure I).

Nonoperative Treatment

Treatment can be handled in nonoperative or operative fashion. Nonoperative treatment is recommended for those who cannot tolerate surgery, such as those with associated medical conditions that could render surgery dangerous. These people have their leg placed in a cast, with the foot in flexion for several weeks while using crutches. This option is generally approached with caution, as a complication from this treatment may be permanent calf weakness. After casting, the patient uses a heel lift for up to 3 months to assist in healing. The patient should undergo physical therapy to restore function. Return to sports is allowed after the athlete is able to pass provocative testing that involves simulation of the chosen sport.

Operative Treatment

Operative treatment is recommended for athletes and the athletic population, including those with physical occupations. Surgical options have less risk of permanent calf weakness, provide better ability to push off, and reduce the chance of reinjury from another rupture.

Surgery should be attempted as soon as possible since the tendon is normally under tension. When unattached, therefore, the tendon may migrate up the leg toward the back of the knee. Surgery includes reattachment of the tendon followed by immobilization, with the foot in partial flexion for several weeks to allow healing. During the initial healing process, patients are kept on crutches and then progressed through partial weight bearing to full weight bearing. A heel lift is generally used after immobilization for 4 to 6 weeks to assist with recovery. Physical therapy is then begun to restore motion and function. Total recovery generally takes several months. Return to sports is generally permitted after healing is complete, physical therapy is completed, and the athlete can pass provocative testing in the chosen sport.

R. Robert Franks

See also Achilles Tendinitis; Ankle Sprain; Calf Strain; Retrocalcaneal Bursitis

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Acromioclavicular (AC) Joint, Separation of

Injury to the acromioclavicular (AC) joint is relatively common during sports participation. Men in their 20s are the most prone to sustaining an AC joint injury. Sports in which athletes are most at risk for an injury to the AC joint include hockey, football, rugby, and soccer, although any contact sport has an increased risk for such an injury.

Anatomy

The AC joint is a diarthrodial joint connecting the distal end of the clavicle to the medial acromion. The ends of these bones are covered with hyaline articular cartilage and are separated from each other by a fibrocartilagenous meniscus–type structure of varying shape and size. The AC joint is surrounded by a thin capsule that is stabilized by four strong AC ligaments (anterior, posterior, superior, and inferior).

The AC ligaments are the primary restraints for anterior-posterior (AP) translation of the clavicle. Of the four ligaments connecting the acromion to the clavicle, the posterior and superior ligaments provide the most support against displacement. It is, therefore, important to maintain their integrity when performing surgical procedures involving the AC joint.

The coracoclavicular (CC) ligament is the primary restraint against superior and inferior translation of the distal clavicle. It connects the inferior surface of the clavicle to the base of the coracoid. The CC ligament is made up of two ligaments—the conoid and trapezoid ligaments. The trapezoid ligament is the more lateral of the two ligaments and also acts as a primary restraint to compression of the AC joint. The normal radiographic distance between the coracoid and the clavicle is 1.3 centimeters. This is clinically important when differentiating incomplete versus complete AC joint separations.

Etiology

Most injuries to the AC joint occur by direct trauma. The classic mechanism of injury to the AC joint is an impact to the lateral aspect of the shoulder with the arm held in adduction. Because of the stronger ligamentous stability of the sternoclavicular joint, the majority of the force sustained during a traumatic event is directed to the AC joint. Falling on an outstretched hand can also injure the AC joint. With this mechanism of injury, the humeral head is forced upward, driving it into the undersurface of the acromion.

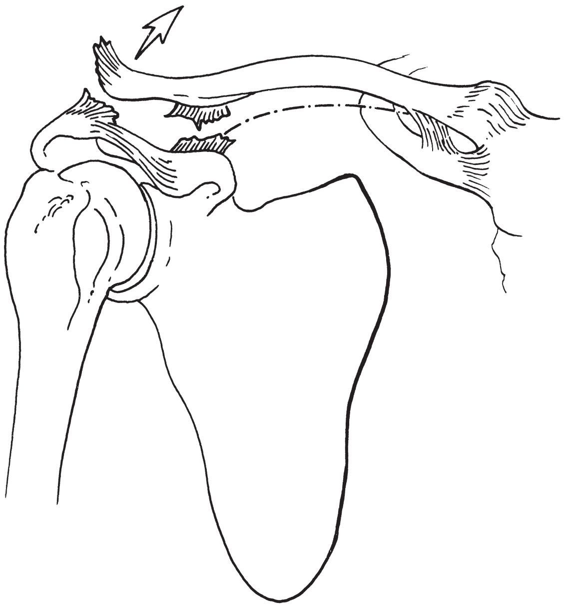

Figure 1 Acromioclavicular Joint Showing Separation

Note: Acromioclavicular joint separation is a sprain (stretch or tear) of the ligaments that connect the scapula (shoulder blade) to the clavicle (collarbone).

Classification

The Rockwood classification of AC joint injuries separates them into six different types. Type I injuries are characterized by a sprain of the AC ligament with no injury to the CC ligaments. Because both ligaments remain intact, no radiographic abnormality is present. In a Type II injury, the AC ligament is completely disrupted, and the CC ligaments are sprained. On radiographs, there is less than 25% superior displacement of the distal clavicle with respect to the acromion. In AC joint injuries of Types III to VI, both AC and CC ligaments are completely disrupted. The clavicle displaces superiorly between 25% and 100% in a Type III injury and greater than 100% in a Type V injury. In a Type IV AC joint injury, the clavicle is displaced posteriorly into or through the trapezius muscle. The clavicle is displaced inferiorly in relation to the acromion and can even be found inferior to the coracoid in a Type VI injury (Figure 1).

Clinical Presentation

Patients who sustain an AC joint dislocation localize pain to the AC joint itself. They may complain of pain radiating to their neck and deltoid. The AC joint may also be swollen. The upper extremity is often held in adduction with the acromion depressed. The clavicle may appear elevated due to the depressed acromion.

The classical presentation is a triad of point tenderness, pain over the AC joint with cross-arm adduction, and relief of symptoms with an injection of a local anesthetic at the AC joint.

Physical Exam

The physical examination of the patient with an injured AC joint should include a neurovascular examination of the upper extremity. The contours of the patient's bilateral shoulders should be compared. In a severe AC joint injury, the shoulder may appear depressed, with a prominent distal clavicle. The AC joint is often swollen and may be tender to palpation. Tenderness along the CC ligaments and at their insertion on the coracoid is helpful in determining the extent of the injury. After an acute injury, range of motion is often restricted, and the patient may not be able to perform specialized tests.

The *cross-arm adduction test* is a specialized test that examines the patient for pain at the AC joint by placing compression across the joint. It is most useful for minor or chronic AC joint injuries. It is performed with the arm elevated to 90° and then adducted across the chest with the elbow bent to approximately 90°. Pain at the AC joint with this maneuver is a positive test.

The *O'Brien test* with pain referred to the AC joint can also be indicative of injury to the AC joint. The test is performed by flexing the shoulder to 90°, pronating the arm so that the thumb is pointing toward the ground, and adducting the arm approximately 15° from the sagittal plane. The patient then resists a downward force placed on the distal forearm by the examiner.

The sternoclavicular joint should also be examined to rule out multiple ligament injuries.

Imaging

The AC joint is best visualized when one third to one half of the X-ray penetration required for glenohumeral joint exposure is used. Standard views of the injured shoulder should include AP, lateral, and axial views (the axial view helps differentiate a Type III from a Type IV injury). A *Zanca view* is a specialized view for imaging the AC joint. It is performed by tilting the X-ray beam 10° to 15° cephalad and using only 50% of the standard shoulder AP penetration strength. The Zanca view is the most accurate view for determining the position of the distal clavicle in relation to the acromion.

A comparison view of the uninjured shoulder can be taken to determine the normal AC and CC joint spaces. Stress or weighted radiographs have not been found to be useful and are no longer a routine part of the work-up of an AC joint injury.

Treatment

Conservative treatment is recommended for Types I and II and most Type III AC joint injuries. Treatment should include ice, analgesics, and sling immobilization for 3 to 7 days. Return to sports is allowed 1 to 2 weeks after Types I and II injuries and 4 to 6 weeks after a Type III injury. Football players may benefit from cutout pads to reduce contact with the AC joint when returning to play.

Treatment for Type III injuries is controversial. Most physicians recommend an initial trial of nonoperative treatment in most cases, including those injuries in professional athletes. An operative approach is, however, considered by some physicians for throwing athletes (particularly baseball pitchers) and people who do heavy labor, whose activities place substantial demands on the upper extremity.

Methods of operative fixation for AC joint injuries include direct ligament repair or ligament reconstruction. Repairs can be augmented with sutures or metallic screws. Ligament reconstruction can be performed by transferring the coracoacromial ligament into the end of the resected distal clavicle or anatomically with an allograft.

After Surgery

Following ligament reconstruction, the arm is supported with a sling and swathe for 4 to 6 weeks. At the 2-week follow-up, gentle range-of-motion exercises with the patient in the supine position are begun. Strengthening and range-of-motion exercises with the arm unsupported in the upright position should be delayed for 4 to 6 weeks to allow the repair sufficient time to heal. Heavy-weight training and return to sports is allowed at 3 months postoperatively.

Jeffrey Vaughn

See also Musculoskeletal Tests, Shoulder; Shoulder Dislocation; Shoulder Injuries; Shoulder Injuries, Surgery for; Shoulder Subluxation

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Acupuncture

Throughout the United States and around the world, people practice what has come to be known as *complementary* and *alternative medicine*. This is medicine that is used as a complement or alternative to conventional Western medicine. One of the most widely recognized practices within complementary medicine is the ancient art of acupuncture. Acupuncture is an age-old practice of working with the body's natural energy flow to achieve balance. Practiced by trained and licensed practitioners, its current uses are many and varied, and its practice is safe and effective.

This entry reviews the philosophy of acupuncture, its methods and uses in and out of the athletic arena, current research on acupuncture, and its future directions.

Philosophy of Acupuncture

Part of traditional Chinese medicine, acupuncture is used to promote health and to maintain the balance of *yin* (cold, slow, passive principle) and *yang* (hot, excited principle). Acupuncture is practiced using a variety of techniques to stimulate specific points on the body and unblock the flow of energy (*qi*) along the body's meridians and, thus, achieve balance.

Practitioners and Practice of Acupuncture

Although the stimulation of specific body points can be practiced in several different ways, the most common acupuncture technique involves the use of thin, solid, stainless steel needles of varying length and gauge, placed at specific body points along the meridians. These needles may be stimulated by movement or by electrical current. The needles themselves are regulated by the Food and Drug Administration (FDA) and are required to be sterile, nontoxic, single use, and used by a licensed practitioner. Another commonly used method of stimulating the body is acupressure, in which the specific body points receive manual manipulation with the therapist's hands and fingers instead of needles.

Although acupuncture practitioners can come from several different professional bases, most states require a license of some kind, although the requirements for attainment of that license (i.e., the specific training) may vary. Although it may seem harmless, potentially dangerous side effects of acupuncture, if performed by an untrained practitioner, include infection and punctured organs. Licensed acupuncturists are those who have studied for 3 or more years in an Oriental college of medicine. Chiropractors can practice acupuncture, provided they have received additional training in acupuncture. Physicians and dentists can also add acupuncture to their practice if they obtain additional training in acupuncture, although the length of required training varies by state, to a maximum of 300 hours. Physicians may also become board certified in acupuncture by the American Board of Medical Acupuncture.

Like other health care visits, acupuncture visits follow a certain format. Typical acupuncture sessions include a discussion of the individual's medical history (e.g., medical conditions, menstrual cycle, eating and sleeping habits), as well as an examination of the patient's posture and mental state (e.g., tone of voice, emotional stress). Sessions can vary in length, although once the needles are in, they usually last from 20 to 30 minutes. Though acupuncture can be used alone, sessions are often accompanied by the use of Chinese herbs, often in the form of an infusion (tea). Many sessions may conclude with recommendations for some lifestyle changes (e.g., change in diet, physical activity).

Uses of Acupuncture

Acupuncture has been employed in treatment of a variety of conditions, ranging from mental conditions and headaches to immune disorders, musculoskeletal problems, and asthma. Acupuncture is extensively used in the sporting arena. Many athletes have found acupuncture an effective method of pain control. Acupuncture has also been used to treat musculoskeletal injuries, as well as to improve performance and prevent injuries. As an adjunct to appropriate training, acupuncture promotes muscle building and glycogen storage, stimulates substrate usage at the time of performance, and treats injuries or other chronic conditions that might affect performance.

Acupuncture has also found its way into the operating room. Acupuncture analgesia is one of the main methods of providing operative analgesia in Beijing and has been found to be beneficial in neurosurgery, thyroid surgery, tonsillectomies, and some open-chest surgeries. Acupuncture research has also demonstrated reduced dependence on conventional pain medications and a decrease of brain activities associated with pain on magnetic resonance imaging (MRI). Although further research is needed, some studies have demonstrated improvement in asthma symptoms with acupuncture, resulting in a decrease of symptoms from exercise-induced asthma when acupuncture was provided before the activity. Acupuncture research has also shown better control of allergic symptoms in patients using acupuncture in conjunction with herbs. Studies of acupuncture and acupressure have demonstrated a decrease in nausea and vomiting in patients after surgery and in those undergoing chemotherapy. The relief and prevention of headaches is another of the studied benefits of acupuncture. Acupuncture has also been noted to promote fertility by improving fertility-related functions, such as improvement in sperm count as well as improved follicular health and ovulation and increased vaginal lubrication.

Acupuncture has been found to be successful in treating addiction to illicit substances. As it is believed that addiction is a self-directed attempt to balance *qi,* acupuncture is said to balance *qi* and has been shown to stimulate the release of endorphins by the peripheral nerves, resulting in increased feelings of well-being, and to provide relief from withdrawal symptoms. Studies have also demonstrated greater relapse prevention with auricular acupuncture. With other mental health conditions, acupuncture helps decrease the duration of hospitalization, as well as improving social interactions, mood, and sleep.

Research and Future Directions

As with many practices of complementary medicine, acupuncture research designs of the past have been difficult to interpret. Currently, the National Institutes of Health (NIH) are conducting several studies on acupuncture, relating to the treatment of low back pain, how acupuncture works, and meridians and *qi* flow. With growing research in acupuncture, practitioners believe that it will increasingly complement and integrate with conventional medicine. Currently, one third of conventional medical schools have curricula that include acupuncture.

Nailah Coleman

See also Bioenergetics of Exercise and Training; Biofeedback; Circadian Rhythms and Exercise; Complementary Treatment; Electrical Stimulation; Electrotherapy; Future Directions in Sports Medicine; Imagery and Visualization; Manual Medicine; Psychological Aspects of Injury and Rehabilitation

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Aerobic Dance, Injuries in

Among the many current approaches to improving cardiovascular fitness is aerobic dance. As with any aerobically oriented conditioning program, the goal is to increase the participant's cardiovascular strength, muscular endurance, and overall wellness. This entry explores the common forms of aerobic dance and how it became popular, as well as common injuries and the ways to prevent them.

Aerobic dance, more commonly called aerobics, is practiced in a class format, often located in community centers, gyms, and fitness centers, but can it also be performed at home using videos or video game consoles. A group fitness instructor leads the class to music with an upbeat tempo so that the participants' heart rates are between 65% and 85% of their maximal heart rate during exercise. Sessions range in length from 30 minutes to 2 hours.

In 1968, Kenneth Cooper published his highly successful book *Aerobics;* aerobic dance entered the fitness industry in the early 1970s, popularized by entertainment and media figures including Judi Sheppard Missett, Richard Simmons, Jane Fonda, and Billy Blanks.

Aerobic dance can be performed as step aerobics, Jazzercise, Zumba, and lightweight resistance training in the form of circuit training. What each of these has in common with the others is the repetitive dynamic nature of moving one's body through different planes of motion with other fitness participants who have similar fitness goals.

Step aerobics, more commonly called aerobics, became popular in the 1980s. It is high impact and has participants stepping up and down in all planes of motion at variable speeds and rhythms. The height of the plastic platform (step) can be adjusted to increase or decrease the intensity of the exercise. The popularity of the original form of step aerobics has diminished somewhat in the past decade with the introduction of modified versions in an effort to counter the increased tendency to injury and with the advent of low-impact aerobic dance classes. The low-impact versions of step aerobics reduce the risk of injury by having exercisers keep one foot always in contact with the surface of the step or floor. With either type of step aerobics, the beat or tempo of the class is kept at either 32 or 64 beats steps^{-1} minute^{-1}. Common injuries associated with step aerobics are patellar tendinitis, Achilles tendinitis, and low back pain. Participants can significantly reduce the chance of these common overuse injuries by being more thorough with their stretching regimen and by cross-training with resistance training and other forms of aerobic exercise.

Low-impact aerobics can come in other forms, such as Nia and Zumba. Nia began in the 1980s and is a blend of several well-known forms of exercise, such as yoga, tai chi, jazz dance, and modern dance. This holistic alternative to step aerobics is popular worldwide and is taught by more than 2,100 instructors.

Zumba originated in the early 2000s and is based on Latin rhythmic dance and creative multiplanar movements; it is currently taught in fitness centers in more than 70 countries around the world. Participants are engaged by a dynamic blend of music and the excitement of an enthusiastic instructor.

Jazzercise was established in 1969, just a year after the publication of *Aerobics*. Currently, according to Jazzercise.com, this form of aerobic dance has 7,800 instructors teaching more than 32,000 classes weekly in more than 30 countries. Jazzercise combines movements seen in yoga, Pilates, kickboxing, and resistance training.

There are a multitude of aerobic dance modalities, each with its own unique style of exercise selection, movement, beat/tempo, and interaction between the instructor and the participants. As with step aerobics, all styles of aerobic dance have an inherent risk of injury. The sheer volume of repetitive motions during aerobics that are not typically sustained in activities of daily living render participants susceptible to the following common overuse injuries:

- Plantar fasciitis
- Heel spurs
- Shin splints
- Sesamoiditis
- Turf toe
- Achilles tendinitis
- Patellar tendinitis
- Knee bursitis

Often these overuse injuries are just a symptom of kinetic chain dysfunction and muscular asymmetries. Symptoms of injury may appear in one area of the body when the "real" or original injury causing these symptoms is in a completely different body part. For example, low back pain can actually be a symptom of tightness in the hip flexor, but the hip will go untreated because of the mistaken belief that it is the back that needs to be "fixed."

It is prudent for participants to consult their physician prior to engaging in an aerobic dance program. People who are just starting exercise should meet with a certified fitness professional or personal trainer for an initial exercise assessment. The fitness professional/personal trainer will be able to provide a novice exerciser with a subjective and objective assessment of needs in order to help prescribe the right blend of exercises to prevent the risk of overuse injury due to preexisting muscular asymmetries. Most fitness centers that host aerobic dance classes also have certified personal trainers who will provide a brief initial assessment of needs and exercise for first-time users. With a clean bill of health from their doctor, participants can enjoy the physical fitness benefits of aerobic dance.

Samuel L. Berry

See also Achilles Tendinitis; Knee Bursitis; Patellar Tendinitis; Plantar Fasciitis and Heel Spurs; Sesamoiditis; Turf Toe

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Aerobic Endurance

Endurance training is regular participation in an exercise program designed to enhance endurance and increase muscle resistance to fatigue. Aerobic energy metabolism is the process by which the body produces energy in the presence of oxygen. Aerobic metabolism is the primary form of energy production during endurance activities such as long-distance running, cycling, swimming, and rowing. Endurance training aims to maximize aerobic energy metabolism through adaptations in the heart, lung, and muscle systems. This type of training can result in improvements in general health, physical fitness, and sports performance while also speeding recovery and rehabilitation from injury or illness.

Background: Energy Metabolism

The body breaks down food in the form of carbohydrates, fats, and proteins to produce energy in the form of adenosine triphosphate (ATP). ATP is the substrate that most cells in the body use as an energy source. ATP can be produced by cells either with or without oxygen. *Aerobic metabolism* is the process by which the body breaks down food to produce ATP in the presence of oxygen. This type of energy metabolism is used during longer-duration, moderate-intensity activities such as jogging. *Anaerobic metabolism* is the process by which body cells quickly produce ATP on demand without relying on oxygen. Muscle cells use anaerobic metabolism for short-duration, high-intensity activities such as sprinting. This type of energy production is short-lived, however, because in addition to producing ATP, anaerobic metabolism also produces lactic acid. Lactic acid accumulation in muscles produces early fatigue. The *lactate threshold* is the point at which lactic acid buildup in the muscles begins to impair performance.

Endurance Training

Power and speed exercises rely primarily on anaerobic metabolism, while endurance activities mostly use aerobic metabolism to produce ATP. Because lactate is not produced during aerobic metabolism, the muscles are able to continue to function without developing early fatigue. Thus, the body is able to continue endurance activities for longer periods of time.

All exercise activities depend on the complex interaction between the *cardiovascular* (heart and blood vessels), *pulmonary* (lungs), and *neuromuscular* (nerves and muscles) *systems*. Oxygen enters the bloodstream through the lungs, the heart pumps the oxygen in the blood through the blood vessels to the muscles, and the muscles use the oxygen in the blood to produce energy through aerobic metabolism. Endurance training is the process by which the body increases the capacity of the heart, lungs, and muscles to produce energy so that the duration and intensity of exercise can be maximized and the onset of muscle fatigue is delayed.

During exercise, both the heart rate (the number of heartbeats per minute) and the stroke volume (the amount of blood pumped out with each heartbeat) increase. This produces a significant increase in the cardiac output (the amount of blood the heart pumps per minute). During exercise, both the respiratory rate (the number of breaths per minute) and the diffusion capacity (the ability of the lungs to absorb oxygen into the blood) increase. This causes an equally increased amount of oxygen to be absorbed into the bloodstream through the lungs. Endurance training produces measurable increases in both the stroke volume of the heart and the diffusion capacity of the lungs. This allows more oxygenated blood to get to the muscles during exercise. Thus, more energy can be produced through aerobic metabolism. This prevents lactic acid from building up in the muscles and causing early muscle fatigue.

Endurance training also produces measurable differences in the muscles. Muscles become both stronger and more efficient at extracting oxygen from the blood. This occurs through an increase in muscle size, an increase in the number of tiny blood vessels inside the muscles, and an increase in the ability of muscle cells to produce energy through aerobic metabolism.

Measuring Aerobic Fitness

Aerobic fitness can be directly measured with special equipment that is used to determine the amount of oxygen the athlete consumes per minute. This figure, called the "$\dot{V}O_2$," can be quantified and steadily increases as the athlete's fitness improves. Another way to measure aerobic fitness is to measure how much lactic acid is accumulating in the blood during exercise. This is done with a blood test following a defined activity. Lower lactic acid levels in the blood following exercise indicate a higher level of aerobic fitness. This shows that the muscle cells are relying on aerobic metabolism and avoiding anaerobic metabolism for energy production. Studies have shown that untrained athletes reach their lactate threshold at lower levels of $\dot{V}O_2$ than trained athletes, indicating that lactic acid buildup occurs slower as fitness or endurance level increases.

Children and Adults

Growing children are still developing their heart, lung, and muscular systems. Compared with adults, children use more oxygen and have higher heart rates, lower stroke volumes, and higher respiratory rates during exercise. Because their muscular system is still developing, children exercise less efficiently than adults and require more energy for any given task. Children also produce more heat and have less efficient cooling systems (i.e., they sweat less) than adults. This makes children more susceptible to changes in climate than adults. On a positive note, children do recover more quickly and experience less pain with intense workouts.

Aerobic endurance has been studied in children and is noted to steadily improve throughout childhood. The greatest increases in aerobic fitness are seen during puberty, which may be related to hormone production and muscular development. Endurance training can produce measurable increases in fitness in children, just like it can in adults. However, for unknown reasons, endurance training in children produces only about one third of the increase in aerobic fitness as compared with what would be expected for adults following a similar training program.

The Ideal Endurance Training Program

An endurance training program consists of activity duration, frequency, and intensity. Typical frequency and duration for aerobic endurance training programs are three to five sessions per week at 30 to 60 minutes per session. Activity intensity may be the most important factor in producing measurable increases in aerobic endurance. Studies have shown that aerobic fitness increases significantly following high-intensity exercise. Activity intensity is usually quantified as a percentage of the maximum heart rate. The maximum heart rate of an athlete can be estimated by subtracting the age of the athlete from 220. High-intensity exercise occurs when the athlete's heart rate reaches 80% of its maximum.

Training Errors

The most common training error is "too much too soon." Sudden increases in training duration, frequency, or intensity are likely to lead to pain and injury. A prudent way to increase training activities is to follow the "10% rule": Do not increase the duration, frequency, or intensity of an activity more than 10% per week. Children are especially susceptible to overuse injuries from overtraining. Before starting any training program, a preparticipation exam and adequate rehabilitation from all injuries is vital. Ignoring persistent pain, especially in children, can lead to significant injuries, including stress fractures and osteochondritis dissecans lesions.

Dennis E. Kramer

See also Exercise Physiology; Exercise Prescription; Knee, Osteochondritis Dissecans of the; Stress Fractures

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Air Pollution, Effects on Exercise and Sports

Air pollution is a problem for all, but it can be a particular problem for athletes. During exercise, both the tidal volume (the volume of one breath) and the respiratory rate increase, resulting in a minute ventilation (the amount of air inhaled in 1 minute) of up to 20 times the resting values. Because of increased ventilation, there is greater delivery of air pollutants to the athlete's airway, which magnifies the deleterious impact of airborne toxins. Also, breathing during exercise is largely through the mouth and not the nose; thus, inhalation bypasses one of the usual means of air filtration, which further increases toxin exposure. Finally, exercise may increase the ease with which compounds cross from the air into the bloodstream. The increased exposure of the athlete is in direct proportion to the level of aerobic work in a given sport and the duration of the exercise; it also depends on the location of the activity, with greater exposure to air pollutants outdoors. Thus, the a marathoner or a cyclist, who may exercise aerobically for hours out of doors, would be expected to suffer more than a swimmer or a weight lifter.

Air Pollution: An Ongoing Concern

Airborne toxin inhalation by athletes has been highlighted in the media during the preparations for many Olympic Games, including the 1984 games in Los Angeles, the 1996 Olympics in Atlanta, the 2004 Athens Olympics, and the recent 2008 games in Beijing. Since vehicle exhaust is a major source of air pollutants, Olympic cities have often initiated strict traffic control policies in the months leading up to the games. For example, prior to the 1996 Olympic games in Atlanta, an integrated 24-hour public transportation system was established, park-and-ride services were instituted, telecommuting and alternate work hours were encouraged by businesses, delivery schedules were altered, and the downtown was closed to private automobile traffic. During this time, all measured pollutants, including ozone, particulate matter <10 micrometer (μm), carbon monoxide (CO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2), decreased significantly. Interestingly, also during this time, pediatric emergency room visits and hospital admissions for asthma were also reduced by over 40%, suggesting that the reduction in air pollution also benefited other vulnerable populations. Beijing, home of the 2008 summer games, is one of the most polluted cities in the world, and it faced similar challenges in improving air quality in anticipation of the Olympics. While their efforts produced the best air quality the city has experienced in 10 years, the levels on most days did not reach the World Health Organization safety limit of an Air Pollution Index (API) of 50. In the weeks and months leading up to the games, some athletes announced that they would not be participating due to pollution-related health concerns.

Relationship Between Air Pollution and Athletic Performance

But how exactly do pollutants affect athletic performance? This depends not only on the sport but also on the specific pollutant in question. The U.S. Environmental Protection Agency (EPA) and similar agencies around the world track the levels of six principal air pollutants, including ground-level ozone, particles, nitrogen dioxide, carbon monoxide, sulfur dioxide, and lead (Table 1).

In addition, volatile organic compounds, a group of airborne hazardous toxins produced by both industrial and natural sources, also have adverse health effects that can be amplified by exposure during exercise.

Ground-Level Ozone

Ground-level (trophospheric) *ozone* (trioxygen, O_3) is the product of reactions between nitrogen oxides and volatile organic compounds containing hydrocarbons. Both of these substrates are produced by combustion from cars, industrial and power plant emissions, gasoline vapors, and chemical solvents, as well as by some sources in nature. Because ozone depends on light for its production, ozone levels tend to be higher on bright sunny summer days. Also, since its removal from the air depends largely on it being deposited on the ground, lack of rain to "wash away" pollutants will result in the accumulation of ozone. These two environmental factors, coupled with air current patterns, have a significant impact on the amount of trophospheric ozone. While stratospheric ozone helps protect us by diffusing harmful ultraviolet radiation from the sun, trophospheric ozone has potentially deleterious health effects. Ozone is known to trigger exacerbations of asthma, increase reactivity to histamine and methacholine, and aggravate bronchitis in animal models and clinical trials. Heavy exposure results in cough, chest pain, throat irritation, dyspnea, nausea, headache, and congestion. It can reduce lung function, cause pulmonary inflammation, and with repeated exposure can result in scarring of the lung and declining lung function.

At rest, an ozone level of 0.4 parts per million (ppm) has been demonstrated to alter airway hyperreactivity in normal subjects; however, during moderate exercise, the level of ozone associated with the development of bronchospasm (airway constriction) may be closer to 0.1 to 0.2 ppm. Independent of exercise, exposure to a high level of ozone (>1 ppm) is associated with increasingly severe respiratory symptoms, and an exposure to 50 ppm for 30 minutes is considered potentially lethal. Ozone may also potentiate the impact of other inhaled pollutants and allergens. For example, ozone pretreatment has been demonstrated to potentiate bronchoconstriction

Table I Air Pollutant Standards Based on World Health Organization (WHO) and National Ambient Air Quality Standards (NAAQS) Guidelines

Pollutant	*WHO Standard*	*NAAQS*	*Impact on Health*	*Notes*
Particulate matter 2.5 µm	10 µg/m^3 (annual mean) 25 µg/m^3 (24-hour mean)	15 µg/m^3 (annual mean) 65 µg/m^3 (98% of 24-hour mean)	Cough, shortness of breath, reduced lung function, cardiac events including ischemia and myocardial infarction, reduced heart rate variability, cancer	Lowest level at which cardiopulmonary and lung cancer mortality rates have been shown to increase with more than 95% confidence interval
Particulate matter 10 µm	20 µg/m^3 (annual mean) 50 µg/m^3 (24-hour mean)	50 µg/m^3 (annual mean) 150 µg/m^3 (24-hour average, not to be exceeded more than once every 3 years)	Same as above	Lowest level at which cardiopulmonary and lung cancer mortality rates have been shown to increase with more than 95% confidence interval
Ozone	100 µg/m^3 (8-hour mean)	0.12 ppm (maximum daily 1-hour average, to be exceeded no more than once per year over 3 consecutive years) 0.08 ppm (3-year average of fourth highest daily 8-hour average)	Cough, wheezing, bronchospasm, chest pain, sore throat, lung inflammation, change in lung function, nausea, headache	
Nitrogen dioxide	40 µg/m^3 (annual mean) 200 µg/m^3 (1-hour mean)	0.053 ppm (annual mean)	Wheezing, cough, bronchospasm, increased susceptibility to respiratory illness	Contributes to acid rain
Sulfur dioxide	20 µg/m^3 (24-hour mean) 500 µg/m^3 (10-minute mean)	0.03 ppm (annual mean) 0.14 ppm (24-hour mean)	Wheezing, cough, bronchospasm, exacerbation of existing heart disease	Contributes to acid rain
Carbon monoxide		9 ppm (10 mg/m^3) (8-hour average, not to be exceeded more than once per year) 35 ppm (40 mg/m^3) (1 hour, not to be exceeded more than once per year)	Low blood oxygen	

Sources: Compiled from WHO and NAAQS data.

Note: ppm = parts per million; µm = micrometer; µg/m^3 = micrograms/cubic meter of air; mg/m^3 = milligrams/cubic meter of air.

in response to sulfur dioxide, another of the six commonly tracked air pollutants. Thus, the deleterious impact of air pollutants appears to be synergistic, and because vehicular exhaust is a common source of many pollutants, environmental exposures are also usually concomitant. Interestingly, although chronic respiratory decline may persist, there appears to be a reduction in the severity of acute respiratory responses to ozone following chronic ozone exposure.

Particle Pollution

Particle pollution is likewise an important factor in air quality. There are two EPA-recognized categories of particle air pollutants: (1) particles less than or equal to 2.5 μm in diameter ($PM_{2.5}$), or fine particles, and (2) those 2.5 to 10 μm in diameter (PM_{10}). Particles 10 μm or larger are typically deposited on the nasal septum; however, this filtering is bypassed during exercise, when most athletes breathe through their mouths. Particles between 2 and 10 μm are typically deposited in the branching airways of the lung, while particles in the 0.2- to 2-μm range are usually deposited in the alveoli, where they are cleared by intra-alveolar cells or absorbed and cleared by the lymphatic circulation. Particles less than 0.2 μm were previously believed to be exhaled; however, growing evidence suggests that these can also be deposited in the alveoli and absorbed into the bloodstream.

$PM_{2.5}$ particles are of particular importance regarding health consequences. Although their chemical composition varies, these particles include sulfate, nitrate, organic carbon, elemental carbon, and organic crust materials. Sources include power generation, car and truck emissions, fertilizers and animal feed, wildfires, and metallurgical mining operations. Exposure has been associated with cough, shortness of breath, impaired lung function, chronic bronchitis, and reduction in normal heart rate variability. Recent evidence supports an association between exposure and myocardial ischemia, heart attack, and premature death. These risks appear to be magnified by exercise.

Carbon Monoxide

Carbon monoxide levels are also closely monitored. Carbon monoxide displaces oxygen from hemoglobin; thus, inhalation of high levels impairs oxygen delivery, which not only limits athletic performance but also may impair other oxygen-dependent body functions. The primary source of carbon monoxide is vehicle exhaust, and in cities an estimated 95% of carbon monoxide is produced by motor vehicles. A study of runners in New York City found that carbon monoxide levels increased from 1.7% to 5.1% following a ½ hour of running near a busy roadway. The elevated level is equal to the typical carbon monoxide level of a chronic cigarette smoker. Carbon monoxide is also identified as exacerbating adverse respiratory and cardiovascular responses to other inhalants, including particulate matter and sulfur dioxide.

Sulfur Dioxide and Nitrogen Dioxide

Like many other pollutants, *sulfur dioxide* and *nitrogen dioxide* are produced by burning fuels. Sulfur dioxide is also a common by-product of oil refining and manufacturing and of metal ore extraction. Both cause acute bronchoconstriction, which can be magnified during exercise. Sulfur dioxide and nitrogen dioxide also both combine with other chemicals in water to produce acid rain.

Volatile Organic Compounds

A final class of chemicals that can be discussed in this context are *volatile organic compounds*. These too are contained in car exhaust, and levels are increased near busy roadways. Common examples include benzene, chloroform, toluene, ethylbenzene, and xylene. Many of these are known carcinogens. Benzene, for example, has been linked with both leukemia and lung cancer. In one study, after only 20 minutes of running along a busy roadway, levels of toluene, ethylbenzene, and xylene were significantly increased compared with the pre-exercise levels; thus, as with other airborne pollutants, exercise in polluted environments increases the exposure of the athlete to these toxins.

Pollution is a worldwide concern. The Kyoto Protocol is an international agreement signed in December 2007 to address global warming through the reduction of environmental pollutants. The agreement expires in 2012, and negotiations are under way for a new international agreement to take its place. Recent efforts exploring alternative energy resources, such as electric and hybrid cars, which are designed to reduce dependence on fossil fuels, are also likely to result in improved environmental conditions. As these efforts move forward, it is likely that the world will become a healthier place for athletes and nonathletes alike.

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See also Allergies; Asthma; Asthma, Exercise-Induced; Outdoor Athlete

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Alcohol and Exercise

The consumption of alcohol has always been thought to help in relaxation, mood alteration, and increasing sensory pleasure. Reducing stress and inducing relaxation have often been cited by athletes and habitual exercisers as the main reason for their alcohol consumption.

Research for many years has focused on the consumption of alcohol and its implications for sports and exercise. Two results are clear: (1) the rate of injury in sports increases with alcohol intake and (2) performance gradually decreases. Whether the use of alcohol is sporadic or over a longer period of time, studies show that when alcohol is present in the body, muscles become inefficient in using glucose and amino acids, which decreases energy. Alcohol also impairs the required metabolic processes during exercise. The cross-sectional area of muscle fibers has been shown to decrease with chronic alcohol use. Consumption after exercise negatively affects blood viscosity. On the other hand, exercise decreases the rate at which the number of mitochondria in the liver declines when one imbibes alcohol. In fact, exercise may increase the rate at which the liver metabolizes alcohol. And exercise perhaps reduces the damaging oxidative effects of alcohol.

Alcohol and Athletes

Alcohol abuse is intertwined with social practices, and sports participants and athletes are not exempt from the tendency to abuse alcohol. In collegiate sports in particular, alcohol misuse is probably underreported, as many studies have confirmed that the problem exists but is often regarded as "normal behavior" by college students.

Studies show varying patterns of alcohol use among the different sports. For example, athletes who play rugby, cricket, hurling, soccer, and Gaelic football have the highest percentage of alcohol consumption. In contrast, the percentage of alcohol consumption among athletes in horse racing, cycling, and tennis is low.

Acute alcohol consumption adversely affects psychomotor skills, and therefore, performance suffers. Acute consumption also reduces the body's ability to adapt to cold environments.

Alcohol and Musculature

Chronic alcohol consumption decreases the vascularity of muscles, and this has been hypothesized to be the cause of its detrimental effects on muscle tissue. Skeletal muscle weight, along with DNA and RNA content, decreases with continuous alcohol use. Alcohol-induced alterations to the normal metabolic processes in muscle tissue, as well as damage to nerves, result in muscle atrophy.

Some studies show that athletes have a higher rate of alcohol consumption immediately prior to their sporting events, and that a significant number of them are chronic alcohol consumers. This situation may be a reflection of the athletes being uninformed about alcohol's detrimental effects, and perhaps the lack of monitoring and education by exercise specialists, training specialists, fitness trainers, coaches, physical therapists, and sports physicians.

In the recovery period after exercise, blood homeostasis, or the ability of blood to maintain normal function, is affected adversely by alcohol consumption, particularly due to alcohol's effects on some clotting factors and hormones. Specifically, blood clotting becomes exaggerated in the recovery phase. There are implications that these alcohol-induced effects on blood homeostasis, along with conventional risk factors such as age, smoking, and abnormal lipid profiles, lead to higher atherosclerosis rates.

Alcohol consumption after a competition or after training appears to be common among athletes. Of particular concern in relation to this practice is the onset of brain infarction, or the development of a blood clot in the brain, leading to decreased blood flow. This was seen in some studies to occur with drinking to the point of intoxication. Although the available evidence does not show a higher incidence of cardiovascular disease with moderate alcohol consumption, some studies suggest that the increase in heart rate, blood flow, and platelet aggregation caused by alcohol may predispose athletes to thrombotic events, or events that lead to blood clots.

In a study examining the effect of alcohol on lipid levels after exercise, no differences were observed in total cholesterol and high-density lipoprotein levels during recovery. Triglycerides, however, increased substantially 5 hours into the recovery period.

Other problems arise from excessive alcohol use. Cardiac muscle is adversely affected by acetaldehyde, an alcohol metabolite. Cardiac dysfunction may result from excessive alcohol use. Arrhythmia may also result from the temporary weakening of left ventricular contraction and the increased myocardial irritability associated with alcohol consumption. These effects appear to be related to acute, heavy use, not to chronic use.

Alcohol and Liver Functions

The toxicity of acetaldehyde (a breakdown product of alcohol) to the liver is well-known, and the fact that alcohol is broken down mainly in the liver leads to a concentration of detrimental effects in this organ. Among heavy drinkers, 10% to 35% develop alcohol hepatitis, and 10% to 20% suffer from liver cirrhosis. In patients with cirrhosis, exercise capacity and oxygen consumption decrease markedly. In alcoholic patients, cardiac dysfunction is very evident, with no increase in left ventricular function during exercise. Impairment of cardiac function has been seen in cirrhotic patients, possibly due to thickening and stiffening of the walls of the heart, ultimately leading to decreased ability to exercise.

Alcohol intake decreases resting glycogen (the storage form of sugar) as well as glucose output. The liver's preoccupation with alcohol metabolism also contributes to decreased production of new sugars for energy. The end result is hypoglycemia, a decrease in blood glucose and, consequently, stored muscle glycogen. Exercise needs glucose as a fuel and taps stored glycogen as well.

Alcohol and Kidney Functions

An increased tendency to urinate is another effect of alcohol. The release of an antidiuretic hormone (a substance that inhibits urination) normally produced by the body so that the kidneys conserve water is reduced by the intake of alcohol. Urine becomes diluted as a result. Dehydration can result if the kidneys do not reabsorb water back into the body. Muscular functions are diminished when electrolytes and essential minerals are excreted in higher concentrations than normal. Total body water drops, specifically affecting muscle functions and nerve conduction because of the loss of the electrolytes potassium, chloride, and magnesium. Moreover, almost all physiological functions become impaired by dehydration.

Athletic performance is greatly affected by body water. A decrease of 1 liter (L)/minute in cardiac output has been observed with each liter of water lost in dehydrated conditions. An elevated heart rate of up to 8 beats $minute^{-1}$ L^{-1} of water lost has been observed as well. Perceived exertion becomes higher because the muscles during exercise are performing harder, but less nutrients and oxygen are available to them. Blood pressure may decrease during dehydration, and central blood volume also decreases, causing the athlete to experience fainting or a "light-headed" feeling.

The ability of the body to transfer heat from contracting muscles to the skin's surface is impaired by consuming alcohol during exercise, and corresponding impairments in blood flow, sweat rate, and blood volume may occur. Heat-related injuries may increase with the faster rise in core body temperature.

Rehydration after alcohol consumption has been shown to be very important in maintaining bodily functions. Because the volume of fluids in the stomach has the greatest influence on gastric emptying, it has been suggested that the sooner the athlete imbibes water, the faster the resolution of the fluid deficit occurs.

Conclusion

Motor skills—reaction time, hand-eye coordination, accuracy, balance, and complex muscle coordination—are adversely affected by alcohol consumption. Mistakes committed on simple musculoskeletal tasks increase with alcohol intoxication. Performance suffers and injuries rise with alcohol abuse, particularly due to the resultant impaired balance, increased reaction time, and decreased accuracy with tasks.

The overwhelming evidence supports the notion that alcohol use hinders exercise and participation in sports. Athletes, in particular, should be counseled against alcohol consumption and constantly educated regarding the body's response to alcohol in terms that they can relate to: performance, maintenance of skills, endurance, strength, and ability.

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See also Cannabinoids; Doping and Performance Enhancement: A New Definition; Risk Factors for Sports Injuries; Stimulants

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Allergic Contact Dermatitis

Allergic contact dermatitis (ACD) is a skin disorder caused by a variety of agents that an athlete may be exposed to during practice or competition. Items such as equipment, local factors on the playing field, and even topical medications in the training room have all been described as potential triggers of this condition. ACD affects all calibers of athletes in all types of sports. Identifying this uncomfortable and debilitating rash, treating it appropriately, and helping to prevent its recurrence is the duty of the sports physician.

Pathophysiology

ACD is an immunologic reaction classified as a Type IV reaction, or *delayed-type hypersensitivity.* The degree of sensitization is variable from person to person, as some individuals may exhibit reaction to some agents, while others do not. For example, the allergen in poison ivy will sensitize nearly 70% of exposed persons, while the chemical allergen found in wetsuits will sensitize a relatively small percentage of individuals.

ACD presents in two stages. The first is called the *induction phase,* which occurs when a person is first exposed to a new allergen. Sensitization by the immune system to this new agent requires a minimum of 4 days to develop. However, many athletes may come in contact with an allergen repeatedly for months or even years before developing clinical sensitivity. The second phase, the *elicitation phase,* occurs after allergic sensitization has occurred. After the athlete is again exposed to the offending allergen, the dermatitis will manifest within 24 to 48 hours.

Prevalence Within Sports

Athletes of nearly every sport played are at risk of developing ACD. From the chemical composition of their gear to the type of tape used in the athletic training room, many different sources of allergens have been reported in a variety of sports.

The incidence of ACD from water sports such as swimming, diving, fishing, and snorkeling has been well documented. The chemicals in the rubber of wetsuits have been described as triggers of this skin condition. In addition, swimmers who are sensitive to the chemicals used to disinfect pools may exhibit the characteristic symptoms of ACD.

Among the myriad skin disorders that plague runners, joggers, and walkers, ACD is especially debilitating. As in other sports, the materials used in manufacturing of training equipment may be responsible for the development of ACD. The inside of the running shoe tends to be moist, and this moisture will leach out the specific chemicals responsible for causing ACD. It has been shown that the neoprene inserts of certain brands of running shoe cause ACD of the soles of the feet.

Soccer players and other field sport athletes are also at risk for ACD. In this population, the skin condition is usually caused by equipment or chemicals used in maintaining the field. Reactions to the lime used in field markings, known as "cement burns," have been found in several athletes. This rash was noted to occur either during or after completion of a match and became worse after a hot shower.

Items commonly found in the athletic training room may also predispose individuals to ACD. There have been many reports of skin reactions to the chemical resins used in athletic tape. It has been reported that analgesic sprays, topical medications, and anti-inflammatory creams/gels have caused ACD in athletes. Other training room products that cause ACD include eucalyptus oil and lanolin preparations.

Diagnosis

To diagnose ACD, the team physician must first recognize the dermatologic manifestation associated with the condition. On sensitization and then reexposure to the allergen, the dermatitis starts to manifest within 24 to 48 hours. An intensely itchy, very red rash develops rapidly, followed by vesicle and/or blister formation. Lesions are usually very well demarcated and will often originate at the site of contact with the allergen; however, new lesions may appear at distant, seemingly unrelated sites as a result of transfer of the allergen by the hands. In time, a chronic stage may occur, characterized by thickened, fissured skin.

There is considerable variation in the intensity of the reaction, depending on the body area affected. The mucous membranes are usually spared, as well as the hair-bearing scalp. Palms and soles tend to be much less affected than the dorsal and interdigital areas. The eyelids and skin around the eyes are especially sensitive, while involvement of the armpits is rare.

Although clinical diagnosis of ACD is the usual practice, the gold standard for formal diagnosis is patch testing. This procedure attempts to re-create the skin manifestation using a minute concentration of the offending allergen. The TRUE Test, manufactured in Denmark, is a commercially available patch testing kit that contains patches with 24 commonly encountered allergens. The upper back is the favored site for testing, and it is imperative that hair be removed using an electric rather than a straight razor to minimize damage to the skin being tested. Patches should remain on the skin for 48 hours and are then removed, with the reading done in 72 to 96 hours. A classically positive patch test reaction consists of reddened skin, mild edema, and small, closely set vesicles.

Treatment

Treatment of ACD depends on the severity of the condition. Acute manifestations are best treated with wet dressings for the first 24 to 36 hours using Burow's solution. Topical steroid creams are useful against mild to moderate ACD. Although rarely needed, oral corticosteroids are effective against severe ACD. Itchy skin and hives are generally well managed with oral or topical diphenhydramine. If secondary infection is suspected, the use of antibiotics may be warranted.

Prevention of future outbreaks should also be a goal for the team physician. Although avoidance of the offending agent is the ideal management, it may not always be feasible. Substitution of alternative equipment, such as nonrubber shoe insoles or eye goggles, may be helpful in this process. In any event, one must be sure that substitution of a certain item with another does not also trigger the allergic reaction.

Return to Sports

The decision surrounding return to play is determined by the athletes' level of discomfort and their willingness to return. Complicating bacterial secondary infection may preclude immediate return and should be addressed on a case-by-case basis. The likelihood of reexposure to the initial trigger should also be taken into account. Prophylaxis with nonsedating antihistamines may be necessary, especially if repeated contact with the offending agent is likely.

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See also Dermatology in Sports; Skin Disorders Affecting Sports Participation

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Allergies

Allergic reactions are caused when the immune system is triggered into action by an *allergen*, which is a protein, or antigen, producing a clinical allergic reaction. These allergens elicit a response by immunoglobulin-E (IgE), causing various symptoms depending on the body system affected. This entry will explore different issues related to allergies, including allergic rhinitis and venom allergies, and how to diagnose and treat different types of allergies. Allergies can significantly affect an athlete's performance; for example, failure to adequately control allergic rhinitis can lead to an increase in upper respiratory symptoms, which can impede an athlete's breathing, resulting in suboptimal performance.

Allergic Rhinitis

Allergic rhinitis is the term used to describe inflammation of the nasal mucosa that causes symptoms ranging from nasal discharge to sneezing to nasal itch. Allergic rhinitis is caused by specific allergens in the environment.

Epidemiology

Allergic rhinitis can occur at any age but most commonly affects children and adolescents, with the mean age of onset around 8 to 11 years. Recent studies and surveys indicate that allergic rhinitis may affect around 40 million people in the United States alone, and the annual health care costs may be around $15 billion. In childhood, it is more common in boys but occurs equally in both sexes in adulthood. Allergic rhinitis can affect persons of all races, and prevalence varies depending on geographic location (i.e., warm vs. cold, rural vs. urban).

Etiology

Pollens and mold spores are the allergens that are generally responsible for seasonal allergies. These pollens usually come from trees, grasses, and weeds that depend on the wind for pollination, which produce large quantities of lightweight pollen that can be breathed in, triggering symptoms. Flowering plants and those plants that depend on insect pollination typically produce a heavier pollen that rarely causes symptoms. The seasons and the location determine the type of allergies a patient may develop. For example, the highly allergenic ragweed is found in the Midwest and the eastern United States and typically produces pollen from August through September. See Table 1 for further details.

Table 1 Common Environmental Allergens

Indoor	*Outdoor*
Dust mites	Weeds (especially ragweed)
Pet dander (most common in cats and dogs)	Trees
Cockroaches (especially important in large cities)	Grasses
Indoor molds	Molds

Pathophysiology

In patients who are susceptible to allergies, exposure to an allergen leads to a cascade of events that result in characteristic symptoms. When a patient is exposed to an allergen, he or she can develop allergic sensitization, which is characterized by the production of specific IgE directed against these antigens. Mast cells, which are present in the nasal mucosa, bind IgE, which leads to immediate and delayed release of a number of chemical mediators. These include histamine, kinins, leukotrienes, prostaglandin D2, and others. Through a series of chemical reactions, these mediators eventually cause the common symptoms associated with allergies, such as nasal congestion, itching, and sneezing. This is the immediate response, and over the next 4 to 8 hours, the late-phase response occurs. This occurs through recruitment of other inflammatory cells such as neutrophils, eosinophils, macrophages, and lymphocytes. All these cause continued inflammation. The symptoms are similar but with more congestion and mucous production and less sneezing and itching.

Diagnosis and Testing

Clinical Features

Patients can present with a wide array of symptoms and complaints, so a detailed history is extremely important in helping to determine not only if a patient has allergic rhinitis but also what allergen in the environment is triggering the symptoms and how best to treat the patient. Things to consider when taking the history include determining if the symptoms are seasonal or perennial (year round), which organ systems are affected, and what triggers the symptoms, such as specific outdoor or animal exposures. Other history to elicit includes response to past medications, exposures at the workplace, and whether there is a family history of allergies. A personal history of asthma or atopic dermatitis correlates with allergic rhinitis.

Physical Examination

The most common physical findings are usually confined to the nose, mouth, ears, and eyes. Patients may have any or all symptoms in any combination. Patients can have “allergic shiners,” which are dark circles under the eyes related to nasal congestion. White, pale, blue-gray turbinates in the nasal exam are consistent with allergic rhinitis. The nose also usually has a thin, clear secretion. A “nasal crease” is a horizontal crease across the lower half of the bridge of the nose caused by repeated upward rubbing of the tip of the nose. This is also known as the “allergic salute” and is seen commonly in children. The ear exam may reveal fluid in the middle ear as a result of Eustachian tube dysfunction. Examination of the eyes may reveal reddened conjunctivae and excessive lacrimation. The throat exam can show “cobblestoning,” which describes streaks of lymphoid tissue in the posterior pharynx.

Testing

Allergic rhinitis can often be diagnosed by the clinical history and the exam findings, but skin testing is helpful to confirm the diagnosis and to determine specific allergen sensitivity. Identifying specific allergens can help direct prevention and treatment. The most common test is the scratch or prick test, in which a drop of extract is scratched or pricked through the skin using a needle or other testing device. The antigen in the extract binds to IgE on skin mast cells, and histamine and other mediators are released, creating a wheal if the patient is allergic to that antigen.

Intradermal testing can also be done, in which the extract is injected into the dermal layer of the skin. Intradermal testing is more sensitive than skin testing, but it also has a higher amount of false-positive results. Radioallergoabsorbant testing (RAST) involves measuring the proportion of specific IgE to allergens in the blood. RAST testing is generally less sensitive than skin testing.

Treatment

Prevention

Treatment can be divided into two categories: (1) prevention/avoidance and (2) pharmacological therapy. Avoidance can consist of using dust mite covers on pillows and on the bed, extermination of cockroaches, or, if the allergen is pet dander, keeping the pet out of the bedroom to minimize the dander in the area where the patient sleeps. Frequent washing of bedsheets, vacuuming, and minimizing the amount of carpet in the house are all strategies that may help. For outdoor allergies, keeping windows and doors closed, minimizing outdoor time during high pollen counts, or wearing a mask when mowing the lawn or gardening are a few strategies that may help prevent allergies.

Pharmacological Therapy

Treatment is determined based on the frequency and severity of the symptoms. Patients with intermittent symptoms may benefit from oral decongestants, oral antihistamines, or both. Patients with more severe or chronic symptoms often benefit from an intranasal steroid spray. Patients with eye symptoms may benefit from ocular antihistamine drops. It is not uncommon for patients to be on a combination of or on all these medications at a time. A leukotriene receptor antagonist can also be added to help relieve symptoms.

Allergen immunotherapy can also be used, with the intention of increasing the threshold level for symptoms to occur after exposure to an allergen. Immunotherapy consists of injections that contain small amounts of the allergens the patient is allergic to, with the expectation that this will help "desensitize" the patient to the offending allergen. Given the expense and the fact this is long-term therapy, it is usually reserved for patients with chronic symptoms that are refractory to the aforementioned medications.

Venom Allergies

Allergic reactions to insect stings constitute a real medical problem, with about 50 deaths per year in the United States. The most common stinging insects are of the order Hymenoptera, which includes yellow jackets, wasps, and bees. The most serious reaction that happens is anaphylaxis, usually occurring within 15 minutes of the sting. Symptoms include generalized urticaria, flushing, angioedema, and edema of the upper airway. Patients may also develop shock and hypotension, resulting in death.

Testing can be done to diagnose venom allergies, and once a diagnosis has been made, venom immunotherapy can be initiated. Patients who are at risk should always carry an epinephrine self-injection device to be used in case they are stung. This is important for athletes who train in warm-weather environments, where they at risk of being stung. They should either carry an epinephrine pen with them, if they are participating in a solo sport or are training by themselves, or have their trainers or medical staff have an epinephrine pen readily available. The epinephrine pen should be renewed every year.

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See also Air Pollution, Effects on Exercise and Sports; Allergic Contact Dermatitis; Asthma; Respiratory Conditions

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Altitude Sickness

High altitude is generally defined as an elevation above sea level greater than 6,500 feet (ft), or 2,000 meters (m). Above this elevation, unacclimatized athletes may develop *altitude sickness*, or acute mountain sickness (AMS), shortly after their ascent. AMS reflects cerebral abnormalities and is one end of a spectrum of severity that includes high-altitude cerebral edema as a more severe potential consequence of ascent. High-altitude pulmonary edema and high-altitude cerebral edema occur at similar altitudes and, though uncommon, are potentially fatal.

Given that most persons traveling to high altitudes are doing so to perform physical activity of some kind, be it skiing, climbing and mountaineering, or competing in an endurance race or soccer match, it is wise to be aware of the deleterious effects of elevation above sea level.

Epidemiology

Epidemiological data from Colorado suggest an incidence of AMS of 22% at altitudes of 1,850 to 2,750 m (7,000 to 9,000 ft) and 42% at altitudes of 3,000 m (10,000 ft). The summit of Mt. Everest is 8,848 m (29,028 ft), which is considered extreme altitude.

Pathophysiology

The reason why altitude can result in AMS appears to be related to the reduced supply of oxygen (***hypoxia***), particularly to the brain and lungs. This deficiency of oxygen stimulates increased blood flow, leading to increased pressure and eventual leakage of fluid out of the smallest blood vessels in these areas. This leakage results in swelling in the brain (*cerebral edema*) or lungs (*pulmonary edema*).

Causes

Risk factors for altitude sickness include residence below 900 m, previous episodes of altitude sickness, physical exertion, and some cardiopulmonary conditions (though not hypertension, coronary artery disease, diabetes, or mild chronic obstructive pulmonary disease). Children appear as susceptible as do adults, while older adults (>50 years old) have decreased susceptibility. Women have an equal risk for altitude sickness, though a lower risk for high-altitude pulmonary edema. Physical fitness has no protective effect.

Persons with previous experience of high-altitude pulmonary edema may have a recurrence rate of 60% should they ascend rapidly to higher than 4,600 m. Such individuals seem to have a reduced ventilatory response to hypoxia and an exaggerated pulmonary pressor response to hypoxia and exercise, though they are otherwise quite healthy. Endothelial function might be responsible for this impairment. Those susceptible to high-altitude pulmonary edema appear to have a genetic difference in their sodium channels.

Definition

Altitude sickness is a relatively subjective syndrome with nonspecific symptoms. The Lake Louise Consensus Group defines altitude sickness as the presence of headache in an unacclimatized individual who has recently arrived at an altitude above 2,500 m, who in addition is experiencing one or more of the following symptoms: anorexia, nausea or vomiting, insomnia, dizziness, and lassitude or fatigue (Figure 1).

Clinical Presentation

Altitude sickness often presents with nonspecific symptoms such as decreased appetite, nausea or vomiting, difficulty sleeping, dizziness, and fatigue. The presence of one or more of these symptoms in an unacclimatized athlete who has recently (typically 6–10 hours earlier) ascended >2,500 m is necessary for a diagnosis. There are no physical signs unless someone progresses to cerebral edema. In this case, changes in consciousness and difficulty with balance and coordination (ataxia) may be present. Eye findings such as papilledema and retinal hemorrhage or even a palsy of one of the cranial nerves may also be present, indicative of the increased intracranial pressure. Drowsiness can progress to stupor and even to brain herniation and death over a period of hours or days.

High-altitude pulmonary edema commonly occurs the second night at a new altitude and rarely after more than 4 days at a given altitude, owing to changes in blood vessels in the lungs. Acute pulmonary edema is suggested by deteriorating performance during activity and breathing difficulty at rest, a "moist" cough, severe weakness, drowsiness, skin color change (cyanosis), increased heart rate and breathing rate, and crackles on auscultation of the lungs with a stethoscope. Orthopnea is rare, but fever up to 38.5 °C is common. Pink or bloody sputum is a late finding.

Diagnosis

Diagnosis of altitude sickness is clinical, and laboratory tests or imaging are not very helpful, unless

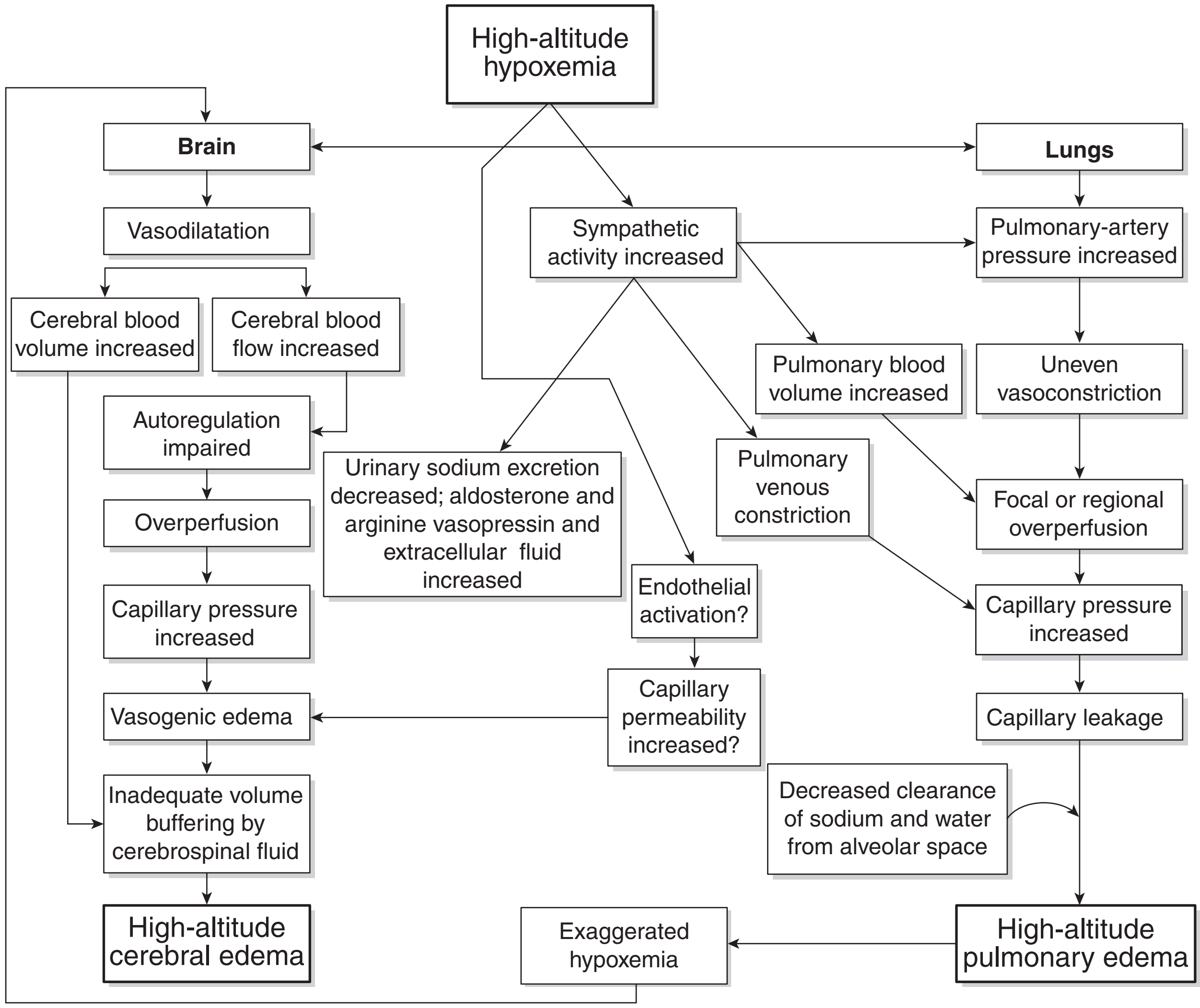

Figure 1 Altitude Sickness Pathophysiology

Source: Hackett PH, Roach RC. High-altitude illness. *New Engl J Med.* 2001;345(2):107–114. Reproduced with permission.

perhaps to exclude another diagnosis. In a patient with pulmonary edema, electrocardiography often demonstrates subtle abnormalities reflecting right heart strain. Chest radiography generally reveals patchy infiltrates, found in both lungs in more severe cases.

Treatment of Altitude Sickness

Treatment of altitude sickness begins with preventing further ascent until the symptoms have resolved. If no response to medical management is seen, descent is also indicated. If cerebral edema is suspected, descent should be immediate. Descent and supplemental oxygen are the treatment of choice; descent can be accomplished in a portable hyperbaric chamber. Acetazolamide appears to reduce symptom severity within 24 hours and is useful when descent or oxygen is not an option. Dexamethasone has been shown to be equally effective, if not superior, and can have a more rapid effect within 12 hours. After altitude sickness has resolved, any further ascent should be made with caution, perhaps with acetazolamide prophylaxis. Other agents have been studied, but results are mixed.

Prevention of Altitude Sickness

The best strategy for the prevention of altitude sickness is a gradual ascent to promote acclimatization. Acclimatization is the physiologic method of progressively increasing sleeping altitude. Published guidelines state that once above 2,500 m, the altitude at which one sleeps should not be increased by more than 600 m in 24 hours and an extra day should be added for every increase of 600 to 1,200 m. Expert opinion recommends prophylaxis for those who plan an ascent from sea level >3,000 m (sleeping altitude) in 1 day and for those with a history of altitude sickness. The old climbers' dictum is "climb high, but sleep low." Maximal acclimatization occurs at 3 to 6 weeks.

Acetazolamide is usually the preferred pharmacotherapy; it should be started 12 to 24 hours before ascent and continued for 3 or 4 days. Dexamethasone is an alternative, and *Ginkgo biloba* also has been shown to be effective.

Treatment of High-Altitude Pulmonary Edema

Treatment of high-altitude pulmonary edema is focused on increasing oxygenation by having the patient breathe supplemental oxygen, which reduces pulmonary artery pressure, reverses the effects of the illness rapidly, and also benefits the brain. Descent, supplemental oxygen, or both are nearly always successful. Patients with severe pulmonary edema, which arterial oxygen saturations have failed to improve, and those with concomitant high-altitude cerebral edema must be moved to a lower altitude and possibly hospitalized. Nifedipine can be used as an adjunct or for prophylaxis; however, it is not as effective as supplemental oxygen.

Altitude and Performance

Maximal oxygen consumption ($\dot{V}O_2max$) will decrease with altitude (~1% per 100 m above 1,500 m) and can significantly affect competitive athletic events. Acclimatizing at altitude for 3 to 6 weeks prior to competition has been recommended, though significant improvements in performance are seen over a shorter window of time, and there is little further improvement after 21 days. Athletes should consider scheduling travel to coincide with a tapering plan that allows for some high-intensity efforts to be performed at the competition altitude before the event. The relative training load should be maintained while considering that maximal exercise capacity will be reduced. This is probably of little benefit for short (<1 minute) anaerobic events and is often impractical. The acclimatization process causes an increase in red blood cell mass and a resultant increase in the oxygen-carrying capacity of blood. An alternative to acclimatization is the use of commercially available hypoxic generator tents, which seem to be as effective over a 3-week period. This effect has been shown to increase aerobic power and exercise performance at sea level, hence the use of "altitude training."

Further Research at Altitude

The brain ultimately regulates exercise effort, but only a few studies have tested this directly. These studies have shown that exercise involving large amounts of muscle (e.g., cycling) at altitude is limited *before* signs of muscle fatigue develop. When subjects are given supplemental oxygen at the point of exhaustion, they are able to continue cycling at higher work rates, suggesting that exercise at altitude may be highly influenced by central factors such as cerebral hypoxia. Athletes who take the time and energy to properly adjust to altitude prior to competition can maximize their potential at altitude. There unfortunately is no "magic bullet," and there is a great deal of individual variation. Coaches and endurance athletes are perhaps best served by avoiding the described medical complications at altitude and allowing their bodies to adjust.

Hamish A. Kerr

See also Aerobic Endurance; Outdoor Athlete

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Amenorrhea in Athletes

Amenorrhea is the absence or cessation of the menstrual cycle in a woman of reproductive age. The disorder is further subdivided into primary and secondary types. Primary amenorrhea is the absence of a menstrual cycle by the age of 15. If the menstrual cycle appears at puberty but subsequently ceases for more than 3 months, the diagnosis is called secondary amenorrhea.

Amenorrhea has several different etiologies. A hormonal interaction between the hypothalamus, pituitary, and ovaries controls the onset of menstruation and the monthly cycle. An abnormality in the function of any one of these organs can lead to amenorrhea. The reproductive tract must also be free from anatomic abnormalities. Last, hormones from outside the hypothalamus-pituitary-ovarian axis can influence the menstrual cycle. These outside influences include thyroid hormone and cortisol.

Exercise and Amenorrhea

Amenorrhea in an athlete represents a unique situation. Excessive exercise can lead to either primary or secondary amenorrhea. Many theories have been explored in an attempt to explain this relationship. As stressful situations such as death in the family or divorce can cause amenorrhea, the stress associated with strenuous exercise may be the cause of amenorrhea in these athletes. Some studies have shown that stress can inhibit certain hormones, which would lead to suppression of menses. Definitive evidence is lacking, and interestingly, adolescents with stressful music careers do not experience a similar disruption in their menstrual cycle.

A second explanation for amenorrhea in a high-level athlete is a disorder of energy balance. If energy expenditure exceeds caloric intake, the athlete's body may allot available energy to necessary functions at the expense of other, nonnecessary functions such as reproduction. This adjustment can occur within one to two menstrual cycles. As a result, athletes with a normal body fat composition can experience menstrual disturbances after relatively short intervals (months) of intensive activity if their dietary intake does not correspondingly increase as well. The energy imbalance may be intentional on the part of the athlete, or it may be accidental. Many adolescent athletes underestimate the additional energy demands of high-intensity exercise.

Anorexia nervosa lies at the end of the spectrum of poor energy balance. This disorder is characterized by refusal to maintain a healthy body weight due to intense fear of gaining weight. Irregular menstrual cycles can occur early in the disease before significant weight loss. Amenorrhea is almost always present in severe weight loss when a female is less than 20% of ideal body weight. Epidemiologic evidence does not show that anorexia is more prevalent in athletes relative to their age-matched counterparts. However, individuals involved in aesthetic sports such as diving, gymnastics, and ballet are at high risk for disordered eating habits.

The Female Athlete Triad

Young female athletes may develop a combination of conditions including irregular menstrual cycles, low bone mineral density, and disordered eating. This cluster of findings is called the *female athlete triad.* Low calorie intake relative to energy expenditure can lead to menstrual disorders as discussed above and also compromised bone strength. The most severe pathology is manifest as anorexia nervosa, amenorrhea, and osteoporosis. These individuals are at risk for stress fractures and are likely at risk for more severe fractures late in life. Few athletes exhibit all three elements of the triad. The signs and symptoms should be viewed on a continuum, and athletes showing suggestions of one sign should be considered at risk for the others.

Clinical Evaluation

A comprehensive history and thorough physical examination should begin the clinical evaluation. Attention should be paid to diet, exercise, menstrual history, and signs of secondary sexual characteristics such as breast development and pubic hair growth. Body mass index (weight in kilograms divided by square of the height in meters) should be calculated and compared with normative values if disordered eating is a consideration. Signs of hormonal abnormalities should be assessed.

Diagnostic Tests

History and physical exam findings can determine appropriate diagnostic testing. Every patient needs a pregnancy test, as one of the most common causes of amenorrhea is pregnancy. Anatomic reproductive abnormalities can be evaluated by pelvic ultrasound in primary amenorrhea. Serum hormone level measurements may be necessary to assess proper endocrine function.

Specific testing for an athlete with elements of the female athlete triad evaluates for signs of energy imbalance. Daily dietary intake needs to be evaluated. Initial labs include evaluation of serum electrolytes, screening for anemia, and assessment of thyroid function. A bone density test can be considered if risk factors are present.

Prevention

Many causes of primary and secondary amenorrhea are associated with genetic predispositions and are not preventable. However, amenorrhea secondary to low energy availability and the female athlete triad are avoidable with awareness. Leading national medical associations emphasize education of athletes, coaches, athletic trainers, and the health care team to help recognize and prevent disordered eating. Athletes should be counseled on proper caloric intake and nutritional requirements, including intake of calcium and vitamin D. Many school departments include screening questions on athletic preparticipation physical exam forms pertaining to elements of the female athlete triad. Screened individuals should be educated and counseled appropriately.

Treatment

Treatment of primary and secondary amenorrhea is aimed at the specific cause. This is focused on treatment of amenorrhea associated with excessive exercise and decreased energy intake. Patients' counseling should involve the physician, athletic trainer, nutritionist, coach, and parents. If a severe eating disorder is suspected, treatment should include a psychiatrist and/or psychologist. Often an increase of 300 to 400 kilocalories (kcal)/day (1 kcal = 4186.8 joules) in the form of an energy bar is sufficient to correct the energy imbalance. Athletes should also be encouraged to take calcium and vitamin D supplements to meet recommended daily requirements. Oral contraceptive pills restore normal menstrual flow but do not address the underlying energy deficit and do not restore bone mineral density.

Gena L. Napier

See also Female Athlete Triad; Menstrual Cycle and Sports Performance; Menstrual Irregularities

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American College of Sports Medicine

The American College of Sports Medicine (ACSM) is the world's largest professional organization of sports medicine physicians, practitioners, and scientists. ACSM, based in Indianapolis, Indiana, was founded in 1954, and currently, there are more than 20,000 national and international members. This organization fosters sports medicine education, clinical practice, and scientific research through multiple media including professional meetings, continuing education, newsletters, publications, leadership organizations, certification, and research funding.

Mission Statement

According to the organization's website, ACSM's mission is as follows:

> The American College of Sports Medicine promotes and integrates scientific research, education, and practical applications of sports medicine and exercise science to maintain and enhance physical performance, fitness, health, and quality of life.

Education

Continuing educational opportunities are made available through ACSM in the form of medical journals, newsletters, conferences (national and international), online courses, certification workshops, and regional chapter meetings. Popular ACSM-hosted conferences attended by thousands of individuals yearly include the Annual Meeting, the Team Physician Course, the Advanced Team Physician Course, and the Health & Fitness Summit & Exposition. Popular publications include *Medicine & Science in Sports Medicine, Exercise and Sport Science Reviews, ACSM's Health & Fitness Journal,* and *Current Sports Medicine Reports*. Through these media, health professionals and exercise scientists network and cooperate by sharing knowledge as well as disseminating research.

Certification

ACSM was the first professional organization to certify individuals as health fitness professionals, and to date, they have certified more than 25,000 individuals. Certifications include two health fitness certifications (Certified Personal Trainer and Certified Health Fitness Specialist) and two clinical certifications (Certified Clinical Exercise Specialist and Registered Clinical Exercise Physiologist). These individuals gain varying levels of training, from personal fitness assessments and rehabilitation to exercise testing, prescription, counseling, and supervision. By choosing a credentialed health fitness professional, the consumer can be assured of being provided expert services by a person who has met the standard requirements and has demonstrated competency in knowledge, skill, and ability.

Research: ACSM Foundation

ACSM has committed considerable time and effort to developing the scientific knowledge that drives clinical practice. Research ideas and data are presented and discussed at its conferences and meetings and at roundtable discussions by worldwide experts. Research papers are consistently disseminated in its scientific journals. In 1984, the ACSM Foundation was founded. Its roles include fundraising, managing endowments, and distributing funds both to the college and to individuals as research awards. Yearly, the ACSM Foundation awards approximately $100,000 in research funding. This funding is often awarded to promising young investigators starting their careers.

Jason J. Diehl

See also American Medical Society for Sports Medicine; American Orthopaedic Society for Sports Medicine; American Osteopathic Academy of Sports Medicine; British Association of Sports and Exercise Medicine

Websites

American College of Sports Medicine: http//www.acsm.org

American Medical Society for Sports Medicine

The American Medical Society for Sports Medicine (AMSSM) was founded in 1991 by five family physicians. The organization was formed specifically to meet the needs of primary care, nonsurgical sports medicine physicians. Its stated mission is to "offer a forum that fosters a collegial relationship among dedicated, competent primary care sports medicine physicians as they seek to improve their individual expertise and raise, with integrity, the general level of sports medicine practice."

AMSSM's membership includes 1,124 members with physicians from all facets of primary care and musculoskeletal medicine. This includes family medicine, pediatrics, internal medicine, emergency medicine, preventive medicine, and physical medicine and rehabilitation.

The AMSSM strives to link the rapidly expanding scientific literature to the practice of clinical medicine. Additional functions of the AMSSM include the following:

- To foster research in sports medicine through provision of grants and awards
- To promote state-of-the-art sports medicine practice via collaboration and publication of clinical monographs and position statements
- To provide cutting-edge educational and networking opportunities via the AMSSM annual meeting and involvement with the American College of Sports Medicine (ACSM) Advanced Team Physician course
- To provide a means for publication of original articles and case studies through its official association with the *Clinical Journal of Sports Medicine*
- To provide online research tools to its members via journal links and a subscription to *Sports Discus*

The goals of the AMSSM are as follows:

- To develop and maintain a national society of primary care sports medicine physicians who share a common philosophy, body of knowledge, and expertise related to sports medicine and its practice
- To provide multidisciplinary educational opportunities for primary care medicine physicians using meetings, video and printed materials, and educational tools
- To encourage and support research in the area of sports medicine
- To work with the AMSSM Foundation
- To encourage and support the development and regular review of the knowledge base in sports medicine
- To develop, and lead in formulating, position statements, guidelines, and educational materials on sports medicine topics for both professional and lay use
- To provide a venue for ideas and information sharing among colleagues on the practical aspects of sports medicine practice and delivery of care
- To represent primary care sports medicine physicians and advertise their ability to give high-quality care to the public
- To promote the health and safety of athletes and physically active individuals through education of all involved in their care

The AMSSM supports research in the area of primary care sports medicine and sponsors the following publications:

Clinical Journal of Sports Medicine

British Journal of Sports Medicine

Sports Discus

Beginner Triathlete Articles

In addition to the above, the AMSSM offers a number of services through its website. These include "Sports Medicine Self Care" and "When to Call a Doctor." These services give information about various topics in sports medicine and advice about sports injuries from a primary care physician's perspective. Information on sports medicine fellowships and how to contact a sports medicine physician is also available on the AMSSM website.

James M. Daniels

Websites

American Medical Society for Sports Medicine: http://www.newamssm.org

American Orthopaedic Society for Sports Medicine

Established in 1972 by a group of renowned orthopedic surgeons, the American Orthopaedic Society for Sports Medicine (AOSSM) is recognized as a world leader in sports medicine education, research, communication, and fellowship. The society works closely with many other sports medicine specialists, including trainers, physical therapists, family physicians, and others, to improve the identification, prevention, treatment, and rehabilitation of sports injuries. Formed originally as a forum for education and research with 100 members, AOSSM today has more than 2,500 members.

AOSSM's members are physicians and allied health professionals who demonstrate scientific leadership, involvement, and dedication in the daily practice of sports medicine. Such activities may include service as a team physician at any level of competition; educating persons involved with the health of athletes; service in local, regional, national, and international competitions; and the presentation of scientific research papers at sports medicine meetings.

The unifying interest of the membership is their concern with the effects of exercise and the monitoring of its impact on active individuals of all ages, abilities, and levels of fitness. While many members treat high-profile athletes who play on professional teams, many others devote their practices to helping out their community by treating players on the local high school or junior college team.

Through research and advances in surgical and rehabilitation techniques, orthopedic sports medicine specialists have been able to treat and rehabilitate athletes whose injuries were once career ending and put them back in the game.

AOSSM Activities

Patient Education Materials

The society develops an array of patient literature to help clinicians meet the information and education needs of their patients.

Clinical Practice Materials

AOSSM develops and disseminates monographs, pocket cards, and other materials that have direct application for orthopedists and others with an active interest in sports medicine. Examples of topic areas developed include concussion management, helmet removal, female anterior cruciate ligament injuries, and the role and responsibilities of team physicians.

Traveling Fellowship Program

This annual international exchange with European and Pacific Rim nations allows selected fellows to travel internationally to lecture on and observe orthopedic sports medicine care.

Sports Medicine Research

AOSSM maintains an active research program, including the First Time Investigators Grant program, the Herklotz/AOSSM Sports Medicine Endowment, and other award programs for outstanding research.

Education

In addition to the educational programs and the society's annual meeting, AOSSM partners with a variety of other medical and/or sports-related organizations to provide quality educational courses, including the NFL (National Football League) Physicians Society, NBA (National Basketball Association) Physicians Society, American College of Sports Medicine, American Medical Society for Sports Medicine, American Academy of Orthopaedic Surgeons, and National Athletic Trainers' Association. To guide these endeavors, as well as to provide members with a framework for their own educational endeavors, the society has developed a CME (continuing medical education) Curriculum.

Lisa Weisenberger

See also Orthopedist in Sports Medicine, Role of

Websites

American Orthopaedic Society for Sports Medicine: http://www.sportsmed.org

American Osteopathic Academy of Sports Medicine

The American Osteopathic Academy of Sports Medicine (AOASM) is a multispecialty, national sports medicine organization. It was chartered by the American Osteopathic Association in 1976 and incorporated in 1987. AOASM physicians are involved in clinical practice, medical education, and research. They provide medical and sports medicine care to athletes at recreational, collegiate, professional, and Olympic levels. Physicians completing osteopathic medical school, residency training, and a sports medicine fellowship are eligible to sit for an exam, which if successfully passed earns them a Certificate of Added Qualifications in Sports Medicine. This certification validates that the physician is trained to provide comprehensive medical management to athletes as well as the general patient population.

The AOASM works collaboratively with other sports medicine groups to develop guidelines for the medical care of athletes, to promote exercise as part of a healthy lifestyle, and to represent its members on relevant political issues. The application of specialized manual medicine skills in the diagnosis, treatment, and prevention of neuromusculoskeletal injuries, disorders, dysfunctions, and diseases is an educational focus for the organization. Members of the AOASM are active as faculty in osteopathic as well as allopathic academic medical institutions. Membership categories provide opportunities for physicians, fellows, residents, medical students, and allied health professionals to participate in the organization.

The AOASM is the oldest primary care–based sports medicine specialty. Osteopathic medicine uses a holistic, comprehensive approach to the prevention, diagnosis, and management of sport- and exercise-related injuries, disorders, dysfunctions, and disease processes. The founders, pioneers and expert sports medicine specialists, realized that while there were several physician organizations that support sports medicine, there was no forum specifically for osteopathic sports medicine physicians.

The purpose of the AOASM is to advance a mutually respectful relationship among dedicated, competent sports medicine specialists and to provide a quality educational resource for AOASM members, allied health sports medicine professionals, and the general public.

The vision of the AOASM is to champion the health, well-being, and safety of athletes and physically active people.

The stated mission of the AOASM is to provide

- an educational forum for physicians and health care professionals to address the quality of health care for individuals in competitive, recreational, occupational, and industrial settings;
- leadership to establish and promote fitness and exercise guidelines and to guide health care policy relating to wellness, physical activities, and sporting events; and
- a collegial environment in which physicians and other health care professionals can expand their content knowledge and enhance their clinical skills in primary care sports medicine.

Michael Henehan

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American Osteopathic Academy of Sports Medicine: http://www.AOASM.org

Anabolic Steroids

Steroids in sports have been in the news for decades, and they continue to be a significant problem in sports. The term *anabolic* means that the chemical induces tissue production, or muscle building. Not all steroids are anabolic (muscle building), and steroids of all kinds have significant therapeutic benefits when used properly.

The term *steroid* includes dozens of different chemical compounds, natural and synthetic, that differ from one another in just a few carbon or hydrogen atoms. The most commonly discussed steroids can be separated into two general groups—corticosteroids and gonadal steroids. *Corticosteroids* are produced naturally in the adrenal glands (just above the kidneys) and include glucocorticoids and mineralocorticoids. Glucocorticoids are widely used as anti-inflammatories and immune system modulators. The glucocorticoid cortisone, in pill form or the injectable form, is used to treat conditions ranging from lupus to asthma to poison ivy. Corticosteroids such as depomedrol are used as injectable treatment for tendinitis or bursitis. Mineralocorticoids help regulate water and electrolyte levels and are not typically used in sports treatment or as performance enhancers.

Gonadal steroids are naturally produced in the ovaries in females and in the testes in males. They help produce secondary sex characteristics such as hair distribution and breast development, as well as prepare the body for reproduction. Estrogen is the predominant feminizing hormone in females, and testosterone is the masculinizing, or virilizing, hormone in males. Testosterone has an anabolic effect, which means that it promotes protein synthesis and cellular production, especially in muscles. It is this anabolic effect that has been used by athletes since the 1930s to aid in tissue healing and to build muscle mass. Anabolic steroids also have a medical role in the controlled treatment of severe burns, short stature, and recently human immunodeficiency virus (HIV)-related wasting.

Anabolic steroid use is banned by all major sports governing bodies, including the National Collegiate Athletic Association (NCAA), International Olympic Committee (IOC), National Football League (NFL), Major League Baseball (MLB), National Hockey League (NHL), and Fédération Internationale de Football Association (FIFA). They are banned both because they give an athlete an unfair competitive advantage and because they can be dangerous to the athlete's health. Even the delivery system of steroids can be dangerous. Injectable steroids require needles, which can pass viruses such as hepatitis and HIV. Oral steroids (pills) can cause liver failure, and anabolic steroids may contribute to liver or brain cancers.

Transdermal steroids are now available in odorless and colorless adhesive patches and creams that are simply placed on the skin and absorbed. This makes their use easier for proper medical treatment but also harder to detect if they are being abused without a prescription. Possession of anabolic steroids without a prescription is a federal crime punishable by fines and prison.

Athletes who use these steroids for performance enhancement often use 10 to 20 times the typical therapeutic dose. They often use them in cycles of 4 to 6 weeks, with a 4- to 6-week steroid-free period. Other chemicals also may be used in conjunction with steroids. For instance, diuretics are used to mask steroid use in urine tests. Other chemicals, such as tamoxifen (an estrogen blocker), are used to combat unwanted side effects such as gynecomastia (breast development in males). These masking agents are considered banned substances and are included in the panel of drugs tested in sports.

Serious side effects from anabolic steroid abuse also include avascular necrosis, which is the breakdown and collapse of joints, especially in the hips. Tendon ruptures may be more common. Blood pressure and cholesterol profiles can be adversely affected, leading to cardiovascular problems, including heart attack and stroke. Other side effects include acne (especially on the back), testicular atrophy, and premature balding. Women who use anabolic steroids may develop masculine features such as an enlarged, squared jaw; male-pattern balding; and coarse body or facial hair. Personality disorders, including outbursts of aggression, may also be exacerbated by anabolic steroids.

Michael O'Brien

See also Doping and Performance Enhancement: A New Definition

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World Anti-Doping Agency (WADA): http://www.wada-ama.org/en

Anaphylaxis, Exercise-Induced

Exercise-induced anaphylaxis is a distinct form of physical allergy with a spectrum of symptoms including itching (pruritus), hives (urticaria), angioedema, wheezing, hypotension, fainting (syncope), and in rare instances even death. Urticaria is an early sign of true anaphylaxis. This entry discusses exercise-induced anaphylaxis, its triggers, how to diagnose the condition, and treatment strategies.

General Considerations

Epidemiology

The age of onset ranges from childhood through adulthood. This condition affects males and females equally, and about half the patients have a history of atopy. Attacks can range from a few times per month to once a year. Most cases have been reported in athletes who exercise regularly. There are some studies that suggest that the severity of the anaphylactic events may decrease over time.

Pathogenesis

The exact mechanism is not known, but mast cells are known to be a factor because studies have shown elevated levels of serum histamine and tryptase during attacks. Studies have also shown mast cell degeneration on skin biopsies done after an attack. There may be a priming phenomenon at work, where one stimulus acts as a cofactor for the reaction to occur. Food, medication, or other factors (see below) may act as the primer, and then the exercise triggers the event. Exercise alone does not cause anaphylaxis, and eating the food without exercise also does not cause an anaphylactic event. An individual must first be "primed" by eating the food, and when this is followed up by exercising (the "trigger"), it has the potential to cause an anaphylactic event.

Triggers/Associated Factors

Exercise-induced anaphylaxis can be triggered by any physical activity, but it is more common in aerobic sports and running. Factors that have been associated with this condition include menstruation, use of aspirin and NSAIDs (nonsteroidal anti-inflammatory drugs), and exposure to cold weather or hot, humid weather. Some patients have a food-dependent variant, where they need to ingest a certain food, then exercise, which provokes an anaphylactic response. Common foods associated with these reactions are celery, wheat, shellfish, cheese, eggs, chicken, hazelnuts, oranges, apples, peaches, grapes, and cabbage.

Diagnosis and Testing

Clinical Signs and Symptoms

Within several minutes of exercising, patients experience a prodromal phase that consists of fatigue, warmth, pruritus, and redness of the skin (erythema). These symptoms then progress to large hives that become confluent and eventually appear as angioedema. If the patient continues to exercise, the attack progresses to systemic anaphylaxis with cardiovascular (hypotension, tachycardia, syncope), respiratory (wheezing, stridor), and gastrointestinal (nausea, vomiting, abdominal pain) symptoms. Once the attack occurs, it can last from 30 minutes to 4 hours. There can also be a later-phase reaction that causes headache, fatigue, and warmth, lasting from 24 to 72 hours.

Testing

The diagnosis can often be made based on history. Exercise testing can be performed, but it is cumbersome. Testing needs to be done in a controlled environment with medical personnel, epinephrine, and resuscitative equipment present. Vital signs and spirometry should be monitored. It is also recommended that an intravenous (IV) line be in place both to draw serum markers and to administer medications if necessary. False-negative challenges are common, so testing may need to be repeated on multiple occasions.

Treatment

Nonpharmacologic

The first step in effective management is to identify and avoid specific foods, medicines, or other triggers. Patients may need to limit the intensity and/or frequency of exercise. The athlete should avoid exercise for 4 to 6 hours after eating and during extremely hot, humid, or cold weather. At the first sign of itching, the patient should stop exercising immediately. The athlete should also *never exercise alone*. It is important to have a partner to exercise with in case of an anaphylactic attack. In extreme cases, the athlete may have to switch sports or even stop exercising altogether. Athletes should also wear a medical bracelet that lets people know they are prone to exercise-induced anaphylaxis and may need to receive epinephrine.

Pharmacologic

In the case of an acute attack, antihistamines can be used as the choice for managing early symptoms such as *pruritus*, but if the antihistamines do not help/stop the attack, epinephrine should be administered. Epinephrine should be the first choice for any severe or rapidly developing symptoms. Administration of IV fluids may also help the patient.

Patients who are identified as prone to exercise-induced anaphylaxis should carry self-injectible epinephrine (EpiPen or TwinJet) at all times, especially while exercising. They should also train/exercise with a partner, who can inject them if necessary. Antihistamine therapy has demonstrated only partial benefits in the prevention of anaphylaxis.

Marc A. Molis and Whitney E. Molis

See also Allergies; Angioedema and Anaphylaxis

Further Readings

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Anatomy and Sports Medicine

This entry is designed to provide the reader with a basic framework for the understanding of gross muscular anatomy as it applies to sports medicine. It is intended as a quick reference to the large muscle groups and their actions rather than a comprehensive anatomical review. The entry's systematic approach to major mechanical motions and the muscles that control them will help the reader become familiar with the various muscle groups that work in a coordinated fashion to control the movements of the human body. To complement the text, it is recommended that the reader consult a standard anatomical atlas to allow visualization and thus a better understanding of musculoskeletal anatomy.

Neck

The motion of the neck is described in terms of rotation, flexion, extension, and side bending (i.e., the motion you would use to touch your ear to your shoulder). The direction of the action can be ipsilateral, which refers to movement in the direction of the contracting muscle, or contralateral, or movement away from the side of the contracting muscle.

Rotation is one of the most important actions of the cervical spine, and it decreases as you move your neck toward the thoracic and lumbar spines. Rotation is accomplished primarily by the sternocleidomastoid, which side bends the neck to the ipsilateral side and rotates contralaterally. Together, both sternocleidomastoid muscles act to flex the neck and raise the sternum to assist in forced inhalation. The anterior and middle scalenes both act to ipsilaterally rotate the neck, as well as to elevate the first rib ipsilaterally. The splenius capitis and splenius cervicis act to rotate the head ipsilaterally.

Side bending is also an important action of the cervical spine. The sternocleidomastoid is involved in cervical side bending. The posterior scalene ipsilaterally side bends the neck and also elevates the second rib. The splenius capitis and splenius cervicis also assist in neck side bending. The erector spinae muscles (iliocostalis, longissimus, and spinalis) are the large deep paraspinal muscles of the back. All three act to ipsilaterally side bend the neck.

Neck flexion refers to the motion used to touch the chin to the chest and is accomplished primarily by the sternocleidomastoid as mentioned above. It is assisted by the longus colli and the longus capitis, which also flex the head and the neck.

Neck extension is the opposite of flexion and is accomplished by many of the muscles listed above, including the splenius cervices, splenius capitis, iliocostalis, longissimus, and spinalis.

Back

The back contains the origins of many of the muscles identified in the previous section. The axial skeleton provides the literal backbone of the human body and protects the spinal cord, which innervates almost all the muscles in the body. The erector spinae muscles extend and side bend the back. The semispinalis also extends the back. The small muscles of the vertebrae (multifidi and rotators) provide rotation, extension, and side bending of the back. The quadratus lumborum side bends the lumbar spine and also depresses the thoracic rib cage.

The scapula is elevated by the trapezius and rhomboid major and rhomboid minor and levator scapula.

Shoulder

The shoulder is a complex ball-and-socket joint comprising the head of the humerus, clavicle, and scapula. The shoulder's central motions are flexion, extension, abduction, adduction, internal rotation, and external rotation, all of which will be described below.

Shoulder Flexion

Shoulder flexion is movement of the shoulder in a forward motion. An example of shoulder flexion can be seen when reaching forward as you would to grasp a door knob. This action is accomplished primarily by the deltoid, pectoralis major, coracobrachialis, and biceps brachii (which is composed of a long head and a short head).

Shoulder Extension

Extension of the shoulder is opposite to flexion. Pure shoulder extension is the movement of the arm directly behind the body, as in receiving a baton in a relay race. This movement is accomplished by the latissimus dorsi, deltoid, teres major, and triceps muscles. The triceps, as the name suggests, consists of three heads that originate from different surfaces but share the same insertion at the olecranon process of the ulna and act to extend the elbow.

Shoulder Adduction and Abduction

Shoulder adduction and abduction serve to move the arm toward and away from the body, respectively, in a lateral motion. They can be visualized by picturing someone doing jumping jacks. When the arm is moved away from the body, the motion is called abduction; the arm moving toward the body is adduction. Adduction is accomplished primarily by the pectoralis major, latissimus dorsi, teres major, triceps, and coracobrachialis. The supraspinatus and deltoid are the two main abductors of the shoulder.

Shoulder External Rotation

An example of external rotation is seen in a tennis backhand stroke. External rotation of the shoulder is primarily attributed to the deltoid, teres minor, and infraspinatus.

Shoulder Internal Rotation

Internal rotation of the shoulder is the opposite of external rotation. When reaching into your back pocket, the primary movement of the shoulder is internal rotation. This movement is achieved through the coordinated movement of the pectoralis major, latissimus dorsi, deltoid, teres major, and subscapularis.

The rotator cuff, which acts primarily to stabilize the humeral head, or the ball of the ball-and-socket shoulder joint, is commonly injured in the older population and overhead-throwing athletes. The four rotator cuff muscles are the teres minor, subscapularis, supraspinatus, and infraspinatus. Several of these muscles have tendons that run under the acromion, a bony prominence off the end of the scapula. These tendons, as well as the subacromial bursae, are commonly compressed and pinched, again in older populations and in overhead-throwing athletes. This compression is commonly referred to as *shoulder impingement*.

Arm, Wrist, and Hand

Forearm Flexion

Flexion of the forearm refers to the shortening of the angle formed at the elbow, bringing the hand closer to the shoulder. The primary muscles involved in forearm flexion are the biceps brachii, brachialis, and brachioradialis. Minor contributions to forearm flexion are provided by the coracobrachialis, pronator teres, palmaris longus, flexor carpi radialis, flexor carpi ulnaris, and flexor digitorum superficialis.

Forearm Extension

Extension of the forearm is, as you would expect, the opposite of flexion. It is the action that serves to increase the angle at the elbow, moving the hand away from the shoulder. This action is primarily accomplished by the triceps brachii. The other muscles that make minor contributions to forearm extension include the extensor carpi radialis longus, extensor carpi radialis brevis, extensor digitorum, extensor carpi ulnaris, and anconeus.

Wrist Flexion

Wrist flexion refers to the movement of the wrist toward the palm. This action is carried out by the flexor carpi radialis, flexor carpi ulnaris, flexor digitorum superficialis and profundus and flexor pollicis longus.

Wrist Extension

Wrist extension is the opposite of flexion and serves to shorten the angle at the back or dorsum of the wrist. The muscles responsible for this action are the extensor carpi radialis longus and brevis, which also abduct the hand at the wrist; the extensor digitorum, which also extends the second to fifth fingers; the extensor digiti minimi, which also extends the fifth digit and adducts the hand; and the extensor carpi ulnaris, which also adducts the hand. Other small muscles that cross the wrist joint may also add to wrist extension but to only a small degree, so they will not be covered here.

Wrist Supination and Pronation

Wrist supination refers to the rotation of the wrist that brings the palm facing up. This is visualized by imagining the hand rotating as if it is holding a bowl of soup. The supinator acts to supinate the forearm. The biceps brachii also adds to the supination. Pronation is the opposing action and acts to rotate the wrist so that the palm is facing down. The pronator quadrates pronates the forearm with the pronator teres.

Hand

The hand is a complex structure as it is involved in fine motor coordination and complex task performance. The muscles of the hand are generally much smaller and have more extensive nerve innervation. Most of the actions of the hand are coordinated movements and use coordinated muscle activity to carry out specific movements. The simple action of typing on a keyboard requires the utilization of a multitude of muscles and must be performed precisely. Because of this, the muscles of the hand will not be covered in detail; rather, the primary action of each muscle will simply be listed for general reference. For understanding of the movements of the hand, some knowledge of joint and bone anatomy is necessary. The main bones of the hand are the carpal bones, the metacarpal bones, and the phalanges. The carpal bones refer to the bones of the wrist and are attached distally and proximally as well as to each other through a complex arrangement of ligaments. Distal to the carpal bones are the metacarpals, which refers to the bony part of each finger within the hand itself. These bones lie within the part of the hand that you would call the palm. Extending out from each metacarpal are the phalanges, the bones of the fingers. Each joint of the finger is referred to as an *interphalangeal joint.* The last knuckle or joint is the distal interphalangeal (DIP) joint; the middle knuckle, the proximal interphalangeal (PIP) joint; and the largest and closest knuckle, the metacarpalphalangeal (MCP) joint, as it lies between the metacarpals and the phalanges of each finger. These are referenced below in relation to the muscles of the hand.

The following muscles originate at the posterior surface of the radius or the ulna, but all have their actions in the hand. These include the abductor pollicis longus, which abducts and extends the thumb; the extensor pollicis brevis, which extends the MCP joint of the thumb; the extensor pollicis, which extends the distal phalanx of the thumb; and the extensor indicis, which acts to extend the second MCP joint.

Hand Intrinsics

Although several of the muscles of the hand have their origins in the forearm, there are many small muscles of the hand that have both their origin and their insertion within the hand. These are referred to as *hand intrinsics*. These include the palmaris brevis, which assists with grip; the umbricals, which flex the MCP joints and extend the interphalangeal joints of the fingers; the palmar interossei, which adduct the fingers toward the third or middle finger; and the dorsal interossei, which abduct the fingers away from the third finger. All the interossei flex the MCP joints and extend the IP joints.

The thenar eminence is the lateral volar (palmar) muscle complex of the hand, composed of three muscles that are all innervated by the median nerve. The abductor pollicis brevis abducts the thumb. The flexor pollicis brevis flexes the MCP joint of the thumb. The opponens pollicis acts to oppose the thumb to the other fingers. The adductor pollicis is not part of the thenar eminence, but it acts to adduct the thumb.

The hypothenar enimence is the medial volar muscle complex of the fifth finger. It contains three muscles that are innervated by the deep branch of the ulnar nerve. The abductor digiti minimi abducts the fifth finger. The flexor digiti minimi flexes the fifth finger. The opponens digiti minimi opposes the fifth finger with the thumb.

Abdomen

There are essentially four muscular layers of the abdominal wall. The innermost layer is the rectus abdominis, which has longitudinal muscle fibers that flex the trunk and stabilize the pelvis. The transversus abdominis has fibers that run perpendicular to the rectus and act to compress and support the abdomen as well as provide static core stabilization. The internal oblique layers run perpendicular to the external oblique and act in conjunction with the external oblique on the opposite side of the body to flex and rotate the trunk toward the side of the contracting internal oblique ("same-side rotator"). The outermost layer is the external oblique, which works as above in conjunction with internal oblique to flex and rotate the trunk and provide core stabilization.

Hip

Hip Flexors

The hip joint is another complex ball-and-socket joint similar to the shoulder; however, as a weight-bearing joint, it can sustain considerable load. The socket of the joint, therefore, is much deeper than that of the shoulder, which allows for greater stability but sacrifices some of the range of motion seen in the shoulder. Hip flexion refers to the hip motion that brings the knee toward the chest.

The major muscles of hip flexion include the iliopsoas, which is made up of the psoas major, psoas minor, and iliacus. Together, these muscles act mainly to flex the hip, but they also contribute to abdominal flexion and hip stabilization. Other hip flexors include the sartorius, which in addition to hip flexion contributes to external hip rotation and knee extension and abduction; the rectus femoris, which also acts in knee extension; the pectineus, whose action includes adduction and internal rotation; and the gracilis.

Hip Extensors

Hip extension is accomplished using primarily the muscles of the posterior thigh and buttocks, which when contracted serve to move the thigh into a midline from a flexed position or the trunk into erection when bent forward. Hip extension is mostly accomplished by the gluteus maximus, the biceps femoris (which is divided into two heads, the long head and the short head), the semitendinosus, and the semimembranosus. A minor contribution is also provided by the adductor magnus and other small pelvic muscles.

Hip Adductors

The movement of adduction is used to describe a direction of limb motion that serves to bring the limb from a lateral position to its more axial alignment. Again, picturing the legs during a jumping jack exercise, one can see abduction when moving away from the midline, and adduction when moving toward. The main hip adductors are the adductor magnus, the adductor brevis, and the adductor longus. A minor contribution to hip adduction is performed by the pectineus and the gracilis.

Hip Abduction

Abduction is similar to adduction but in the opposite direction. This action moves the limb away from midline in a lateral direction to the plane of the body. The main abductors of the hip are the gluteus medius, gluteus minimus, and tensor fascia lata. These three muscles also serve to internally rotate the thigh in an extended position and externally rotate the thigh in the flexed position. Another minor contributor is the piriformis.

Hip internal rotation and external rotation are complex movements. As these motions include many muscle groups and depend entirely on the position of the hip, they fall outside the scope of this entry.

Knee

Knee Extension

Extension of the knee is accomplished by a group of muscles collectively referred to as the *quadriceps femoris* (or "Quads"), which increases the angle of the knee, bringing the lower leg into a straight position. Knee extension is used in the forward, swing phase of the gait and is integral in movements such as kicking. This group includes the vastus medius, vastus lateralis, and vastus intermedius and the rectus femoris, which overlies the above three muscles. A minor contribution is provided by the sartorius.

Knee Flexion

Knee flexion refers to bending of the knee from the straight position and is again an essential motion in a normal gait. The muscles that perform this action oppose those of knee extension and are generally referred to as the *hamstring muscles*. Weakness of this muscle group is believed to contribute to anterior cruciate ligament (ACL) instability, resulting in ACL rupture, a common sports injury. Knee flexion is a coordinated effort that includes the biceps femoris and the semimembranosus and semitendinosus muscles. Small contributions are made by the gastrocnemius and several other smaller and less significant muscles that cross the knee joint posteriorly.

Ankle and Foot

Ankle Dorsiflexion

The muscles of the lower leg and foot are very complex and work in many planes. Their actions depend not only on whether the person is weight bearing but also on the position of the foot. Following is a brief overview of these actions.

Dorsiflexion refers to ankle flexion in the direction of the dorsum, or anterior surface of the foot (the surface of the foot viewed from above). Dorsiflexion is accomplished by several muscles that typically have multiple functions. The tibialis anterior, which in addition to dorsiflexion also inverts the foot, stabilizes the foot when striking and locks the ankle when kicking. The extensor digitorum longus (EDL) acts simultaneously with foot extension to extend the last four toes. In addition to the EDL, approximately 20% of individuals have a muscle called the *peroneus tertius*. The extensor hallucis longus primarily acts in big toe dorsiflexion, but it also acts to dorsiflex, as well as weakly invert, the ankle.

Ankle Plantarflexion

Plantarflexion refers to flexion of the ankle in the direction of the sole of the foot. This is most easily demonstrated by having a person stand on his or her toes. The majority of ankle plantarflexion is performed by the large calf musculature that includes the gastrocnemius and the soleus (which lies just behind the gastrocnemius). It is generally accepted that these are two distinct muscles; however, there is some debate as to whether the gastrocnemius and the soleus are two parts of the same muscle.

Other smaller muscles include the plantaris, which runs obliquely between the gastrocnemius and the soleus; the flexor hallucis longus, which contributes to ankle flexion but primarily big toe flexion; the flexor digitorum longus, which also flexes the second to fifth toes; the peroneus longus, which flexes the ankle and everts the foot; and the peroneus brevis, which, in addition to plantarflexion, everts the foot.

Foot Intrinsics

Foot intrinsics, similar to hand intrinsics, are muscles that arise from the foot and do not cross the ankle joint and whose action is confined to the foot. The bones of the foot are similar in nature to those of the hand, but the bones of the foot are referred to as *tarsal* (instead of carpal) *bones*.

The intrinsic muscles of the foot include the abductor hallucis, which adducts the big toe; the flexor digitorum brevis, which flexes the second to fifth toes; the abductor digiti minimi, which abducts and flexes the fifth toe; the quadratus plantae, which assists in toe flexion; the lumbricals, which flex the metatarsalphalangeal (MTP) joints and extend the DIP and PIP joints; the flexor hallucis brevis, which flexes the big toe; and the adductor hallucis, which has two heads that share an insertion on the lateral side of the base of the proximal phalanx of the big toe—the oblique head arises from the base of the second to fourth metatarsal bones, and the transverse head arises from the ligaments of the MTP joints of the third to fifth toes, the action of which is to adduct the big toe. The flexor digiti minimi brevis extends and adducts the fifth toe. The dorsal interossei abduct the toes, and the plantar interossei adduct the toes.

Shane W. Cummings and Christopher Tangen

See also Head Injuries; Knee Injuries; Neck and Upper Back Injuries; Shoulder Injuries

Anemia

Anemia is a condition resulting in reduced numbers of red blood cells. It limits the ability of the blood to carry oxygen and other nutrients around the body and the excretion of waste products (carbon dioxide). The reduction in the red blood cells results in the starvation of tissues of oxygen and nutrients. Anemia may occur in a variety of people, especially athletes.

Persons with anemia feel tired and become fatigued easily. Symptoms of anemia may include the following:

- Paleness
- Weakness
- Chest pains (severe cases)
- Shortness of breath (severe cases)
- Heart palpitations (severe cases)
- An increased heart rate
- Weight loss
- Fatigue
- Numbness and tingling in the hands and feet
- Depression

Women are more likely than men to have anemia due to menstruation. Of the various causes of anemia, only some are mentioned here to present a brief idea of the condition:

- External bleeding/trauma
- Chronic disease
- Iron deficiency anemia
  - Loss of iron at a greater rate than normal (blood loss)
  - Poor absorption of iron
  - Low-iron diet

- Vitamin B_{12} anemia
  - Failure of the stomach lining to produce intrinsic factor
  - Removal of the small intestine
  - Crohn disease
- Folic acid deficiency
- Pregnancy
- Alcoholism
- Bleeding disorders
- Infection
- Hereditary conditions

Although there are more than 400 different forms of anemia, this entry addresses only those anemias related to or caused by sports.

Sports Anemia

Sports anemia refers to a period in early training when athletes develop low blood hemoglobin for a while, likely reflecting normal adaptation to physical training. Aerobic training increases blood volume, fluid volume, and red blood cell count. While true anemia requires treatment, temporary reduced red blood cell count seen early in training goes away by itself after a while.

Physically active young women, especially those engaging in endurance activities such as distance running, are prone to iron deficiency. Iron status may be affected by exercise in a number of ways. One possibility is that iron is lost in sweat, and although the sweat of trained athletes contains less iron than that of others, it is simply an adaptation to conditioning. Still, athletes sweat more profusely than sedentary people.

In addition, in some athletes at least, physical activity may cause small blood losses through the digestive tract when they take aspirin for sores or to relieve pain.

Low intake of iron-rich foods, combined with iron losses aggravated by physical activity, leads to iron deficiency in physically active individuals. It impairs physical performance because iron is crucial to the body's handling of oxygen. Since one consequence of iron deficiency anemia is impaired oxygen transport, aerobic work capacity is reduced because the person tires very easily.

Sports Hematology

The most common finding in athletes is a dilutional *pseudoanemia* that is caused by a plasma volume expansion rather than an actual blood loss. Pseudoanemia is not a pathological state and normalizes with training cessation in 3 to 5 days. Pseudoanemia should be distinguished from conditions associated with lowered blood counts. To determine the true anemia state in an athlete, one must take into account not only blood losses secondary to exercise, such as foot strike hemolysis or iron losses through sweat, but losses due to nonathletic causes as well. Depending on the age and sex of the athlete, consideration must be given to evaluation of the gastrointestinal or genitourinary systems for blood loss. Finally, a comprehensive nutritional history must be taken, as athletes, especially women, frequently do not consume adequate dietary iron.

Although experiments with blood doping revealed improvements in running time to exhaustion and maximal oxygen uptake, the introduction of recombinant erythropoietin has rendered blood doping little more than a historical footnote. However, improvements in performance are not without risk, and use of exogenous erythropoietin has the potential for increased viscosity of the blood and thrombosis with potentially fatal results.

Pseudoanemia

Regular physical training leads to an increase of plasma volume by 10% to 20%. Therefore, a hemoglobin concentration slightly below normal values in the presence of low-normal serum ferritin levels in athletes is usually due to a dilutional pseudoanemia. Since regular physical activity increases iron loss, mild iron deficiency and sometimes true iron deficiency anemia can occur, especially when nutritional iron intake is insufficient and iron demand is increased because of growth or additional iron loss (menstruation).

Iron Deficiency in Female Athletes

Low levels of iron in the body are caused by several mechanisms and become symptomatic with the onset of iron deficiency anemia. Female athletes have an additional source of blood loss, menstruation. However, the most common cause of low hemoglobin levels in an athlete is dilutional pseudoanemia. Athletes are more sensitive to the effects of anemia and iron deficiency as exercise performance depends on maximal oxygen-carrying capacity to the active muscle and efficient oxygen utilization. Iron deficiency without anemia can also reduce athletic performance. Diagnosis is made by a blood count and red blood cell parameters, with ferritin serving as an index of body iron stores.

Iron Status in Athletes

Iron replacement would clearly be indicated if iron deficiency was present but would not be necessary if the observed changes were simply a physiological response. It is acknowledged that serum ferritin and hemoglobin decrease with some exercise conditions. Expansion of plasma volume and the shift of iron storage from the bone marrow to the liver show that the apparent reduced-iron status occurring with exercise is misleading. Iron deficiency is common in the general population, particularly women. Therefore, continued monitoring of iron status in athletes is necessary.

Football Players

It is important to monitor levels of serum iron and other factors of iron metabolism and oxygen transport as they play an important role in the functional ability of football players. A decrease in serum iron level can be the very first sign of development of iron deficiency anemia.

A significant decrease in serum iron level among footballers during both half-seasons is most probably due to increased loss and/or diminished absorption resulting from a high-intensity training process. Because the decline in serum iron may be an early sign of iron store depletion and iron deficiency anemia, it is important to evaluate it regularly, along with other factors of iron metabolism and oxygen transport.

Cyclists and Runners

Another cause of iron loss is red blood cell destruction; blood cells are crushed when body tissues (soles of the feet) make high-impact contact with an unyielding surface (the ground). This usually occurs in long-distance runners and cyclists. This occurs alongside pseudoanemia.

Supplements and Blood Doping

Athletes tend to have lower hemoglobin concentrations than their sedentary counterparts; this is called *sports anemia*. It is a false anemia and a beneficial adaptation to aerobic exercise, caused by an expanded plasma volume that dilutes red blood cells. Athletes, however, can also develop true anemia, most commonly caused by iron deficiency. True anemia inhibits athletic performance, but nonanemic iron deficiency does not. Iron supplements are useful for women endurance athletes who repeatedly develop iron deficiency anemia despite dietary advice. Supplementation improves performance only when hemoglobin concentration increases. Some endurance athletes today are blood doping by abusing recombinant human erythropoietin (rEPO).

Prophylaxis and Correction

Antioxidants, detoxicants, and membrane protectors are used. These treatments have a beneficial effect on the content of hemoglobin in erythrocytes. They appear beneficial to mechanisms of development of anemia during oxidative stress and are used for correction of the functional state of sportsmen.

Other therapies for anemia may include oxygen, fluids, fresh frozen plasma, platelet replacement, and vasopressors (medication to elevate blood pressure).

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See also Dietary Supplements and Vitamins; Female Athlete; Nutrition and Hydration

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Anger and Violence in Sports

Violence and sports have been linked together, misleadingly, for the past several decades due to incidents where athletes have engaged in either unsportsmanlike or, in the extreme, criminally aggressive behavior inside or outside their sporting arena. Consistent with this theme, anger has been implicated as a “bad emotion” that always leads to violence. The evidence that athletes are more angry or violent than nonathletes is spurious at best and gathers the bulk of its support from isolated incidents where athletes have transgressed, sometimes with very public and very extreme displays.

Theories Associated With Sports and Violence

Five theories are outlined below to illustrate the relationship between anger and aggression in sports. This provides a historical perspective of the thinking in the field and will lay the foundation for how interventions have been developed.

Frustration-Aggression Hypothesis

The earliest theory explaining the origins of aggression was the frustration-aggression hypothesis, advanced by John Dollard and his colleagues at Yale in 1939, which stated that aggression was always a consequence of frustration. *Frustration* was defined as occurring at times when the subject was unable to reach his or her goal. And though there have been several theories that have added to and refined this, it is easy to see this theory's application to the world of athletics. In fact, considering how frequently athletes try and do not succeed, it is perhaps surprising that athletes are not more aggressive.

Completion Hypothesis

Thirty years after the frustration-aggression hypothesis was introduced, Leonard Berkowitz put forward the completion hypothesis, which proposed that it was not just frustration that would lead to aggression, but when one experiences an aversive stimulus—which could be heat, noise, or fatigue—one is more likely to experience negative emotions, and these stressors, modulated by one's associated thoughts, lead to the instigation of aggressive behavior. For athletes, this could be exhaustion from training camp, the pain of nagging injuries that will not go away, the boos of the crowd, or the criticism of coaches or the media. The ability to prevent these stressors from affecting one's emotional, and in turn physical, volatility is one component of mental toughness.

Catharsis

Originating in the writings of Sigmund Freud, *catharsis* is the concept that emotions that are not released can build up, like steam in a pressure cooker, and the releasing of that energy is necessary for the individual's well-being. In sport, there are many opportunities for cathartic release, and the visceral satisfaction of dominance, especially amplified by the praise of the coaches and the roar of the crowd, can easily goad an athlete to be violent. The difficult task is to teach athletes when and how to release their pent-up energy in a focused, goal-directed manner that assists, rather than detracts from, their success in sports.

Behavioral Conditioning

Violence, like any other behavior, will increase or decrease in frequency based on the reinforcement or punishment that follows it. In sports, this is especially the case, but it can also be very confusing for an athlete. If a football player is lauded for sacking the quarterback and ending a drive, he is going to be more driven to repeat this behavior. Add to the equation that the player is to attempt to tackle the quarterback but must do so before he passes the ball. If he hits the quarterback after he throws the ball, not only is it a penalty, which hurts his team, but he may be suspended from play and/or fined at the professional level. This creates a differential reinforcement paradigm that can lead athletes to engage in aggressive behavior that falls within the rules of the game in one venue but is illegal in another.

The belief is that in contact and collision sports, the positive reinforcement so outweighs the punishment for aggressiveness that those participants are bound to be more violent. The logic makes sense, and athletes could benefit from learning skills to control their emotions and behavior, but the research is insufficient to conclude that athletes who play contact and collision sports are more likely than others to be violent.

Inverted-U Hypothesis (Yerkes-Dodson Law)

The inverted-U hypothesis, an updated version of the Yerkes Dodson law originally postulated in 1908, describes a curvilinear relationship between performance and arousal. Simply stated, as arousal increases, performance increases as well, but only up to a point. After that point is reached, performance decreases.

Studies of emotion in sports have supported this theory to a degree but with caveats. Individual differences have been noted, because different people experience emotion differently and it affects their performance differently. Also, there are task differences, meaning that some tasks have higher or lower levels of arousal before performance starts to decline. An example of this is related to anger arousal and different sports. A skill that requires fine motor coordination and concentration, such as putting in golf, will be negatively affected by comparatively lower levels of anger than the game of a football player when a defensive lineman is bull-rushing an opposing blocker, where higher levels of anger arousal may augment performance. Overall, anger at low and moderate levels can improve sports performance as it can contribute to increased stamina, energy, and strength with a lower perception of pain, but like other emotions, at higher levels, it can have a negative impact on performance.

Definitions

Anger

Anger is a normal emotion that everyone experiences from time to time in varying intensities. The body responds to anger with physiological arousal of the sympathetic nervous system. Often, anger is experienced in response to a real or perceived threat, insult, or provocation, but it can also stem from generalized irritability. Anger as an emotion should not be confused with the behavior that follows an emotion. Anger is an emotion that can be acted on outwardly, as in arguments or fights, or inwardly in the form of depression or anxiety. People sometimes believe that they get into trouble when they get angry. People do not necessarily get into trouble whenever they are angry, but they may get into trouble for what they do when they are angry. At very high levels, as explained in the previous section, anger can interfere with performance. Extreme anger can lead to poor decision making, decrease in fine motor coordination, slowing of cognitive processing speed, and impulsivity. At low and moderate levels, however, anger can improve sports performance by increasing strength and stamina while decreasing the experience of pain and exhaustion.

Aggression

Aggression has often been used to describe behavior with the intent to harm someone. This is but one aspect of aggression. Being aggressive is a positive quality that leads to success in sports and in life because it refers to the tenacity with which a person pursues his or her goals, thus the delineation of instrumental versus reactive aggression. *Instrumental aggression* in sports is aggression whereby the main intention is to achieve a sports-related goal. It may happen that an opponent, a teammate, or even the athlete himself may get injured in the process, but this is a side effect of the action, not the goal. An example may be a basketball player driving hard toward the basket for a layup and accidentally striking an approaching opponent in the chest with an elbow. The goal was to score the basket, not to injure the opponent. Instrumental aggression is the type of aggressiveness that needs to be harnessed and encouraged to lead to success in sports.

Reactive aggression, however, is behavior that has harming another as the primary goal. It is related to extreme anger and is usually a response to a perceived injustice by another player. An example would be a pitcher who throws the baseball at the head of the batter who hit a home run off him when previously at bat. It is reactive aggression that is of concern for athletes on and off the field.

Violence

Reactive aggression in its most extreme form is *violence*. Sports violence has been defined by sport psychologists as harm-inducing behavior outside the rules of sport, bearing no direct relationship to the competitive goals of sport.

Not all violence is related to anger, and there are times when violence may actually look like instrumental aggression. The coach who instructs players to injure another athlete so as to give their own team a better chance to win is not acting out of anger but with the goal of winning, although by doing so he is exhibiting and fostering exceedingly poor sportsmanship. Thus, reactive aggression may be spontaneous, in response to a set of circumstances, and needs to be curtailed because of the likelihood of player injury; it is far more distressing when there is a systematic plan to injure someone. This behavior is premeditated and criminal and has no place in sports.

Assertiveness

The term *assertiveness* has at times been used interchangeably with *instrumental aggression*. They are, however, very different. Assertiveness refers to one's willingness to stand up for one's rights. It is an important quality for athletes to have when communicating with their coach, their teammates, or other people in their life. Assertiveness is a style of communication; it is not aggressiveness.

Hostility

Hostility is a description of personal temperament; a hostile person is one whose predominant trait is anger. Often having a hostility bias, those with chronic anger tend to perceive neutral stimuli as provocative and have difficulty finding nonprovocative explanations for events (i.e., a hostile person may imagine that the person who bumped into her walking down the hall *must* have done so out of malice rather than by accident); such a person will have trouble generating nonviolent responses to such situations.

Violence in Sports

The public perception of athletes' tendency toward violence has been perpetuated by the heightened attention that athletes receive. Furthermore, the attention that an athlete receives may be compounded by the popularity of that athlete, the level of competition (professionals get more attention than amateurs), and the concentration of media attention given to sports in a particular region.

Using the broadest definition of *athlete,* athletes represent a population of millions worldwide, and there is no evidence that athlete identification is connected with violence. There have been studies that have associated athletes with elevated levels on anger scales, increased incidence of deviant behavior as compared with their nonathlete cohorts, and overrepresentation in sexual assault studies. These studies have many limitations, and the conclusions have limited generalizability.

The main reason why there is a perception that athletes are more violent than nonathletes is that so much attention is paid to sports and their participants. When an athlete is involved in a transgression, it is swept up by the media very quickly, as if to imply that being an athlete is somehow contributory to such behavior, whereas a nonathlete may engage in the same behavior without it being publicized.

Prisons in the United States are not overrun with athletes, and those who were athletes are in jail for their criminal behavior, not their athletic behavior. Similarly, there is no way to identify how many youths were diverted by their involvement in sports activities who otherwise would have gone down the path of violence.

There are athletes who engage in violent behavior. Considering the ubiquity of violence in our society, it would be unrealistic to believe that sports involvement could provide sufficient insulation to make athletes exempt from this trend. However, there is insufficient evidence to conclude that athletes are more violent than their nonathlete peers.

Problems With Research

One of the central reasons why studying anger and violence in sports is so difficult is that measuring those constructs has limited generalizability. This is true in the clinical literature as well. It is a mistake to assume that people who score high on anger scales always become violent. Questionnaires have limitations as how people report their emotions, attitudes, and behavior. Because questionnaires are often the best tool researchers have, despite their shortcomings, it is important to identify what has been used both to springboard further research with them as well as to stimulate the development of other methods of assessing anger and violence in athletes for future use. The instruments that have been used the most in the sport psychology literature are the Profile of Mood States (POMS) and the State Trait Anger Expression Inventory—second edition (STAXI-2). Other instruments that have been used less frequently but show promise are Bredemeier's Athletic Aggression Inventory (BAAGI) and the Competitive Aggressiveness and Anger Scale (CAAS), developed by Jon Maxwell and his colleagues.

Observation of behavior is challenging unless an individual is acting out with high regularity. This is unlikely as this type of behavior tends to select the athlete out of competition; the behavior hurts the team's performance, and the athlete then sees less playing time.

Arrest records are also misleading because an arrest does not necessarily indicate guilt. Furthermore, many factors go into whether or not someone is convicted, with innocence being only one of them; so the number of convictions cannot be used as an indicator either. Often, the quality of representation is a strong predictor of trial outcome and length of sentence.

For this reason, athletes who are involved in high-revenue sports and make more money should not be compared with other athletes with regard to brushes with the law, but rather, they should be considered along with other celebrities, such as music and film entertainers. If this is done, the impression that athletes are not held accountable for their deviant behavior might be understood in a more appropriate context.

Admittedly, the field of sport psychology needs to study the relationship between anger, sports, and violence in greater detail.

Athletes at Risk

Because athletes are under greater scrutiny than most people, they are often held to a higher standard. Therefore, anger management skills, which are life skills that all people need to learn, become even more important for athletes who may be measured with a lower threshold of acceptability.

Additionally, behavior that is considered a normal part of the game may be illegal when preformed outside the sports arena. For example, tackling someone is an expectation on the football field but is considered as assault outside that domain. This presents a potential stimulus differentiation problem for athletes as the same behavior will be differentially reinforced or punished in different contexts. It therefore becomes incumbent on coaches, administrators, and parents to teach young athletes how to recognize and regulate their emotional states so as to be in the best position to control their behavior on and off the field.

Drugs and Violence

Though outside the sports arena drugs and violence tend to go hand in hand, drugs are rarely the explanation offered for an athlete's propensity for hostile aggression. The most popular exception to this are *anabolic androgenic steroids* (AAS), drugs that increase testosterone levels, strength, muscle mass, and speed and, as a whole, present an opportunity for unfair advantage as athletes can outperform their "normal" biological limits. The term *roid rage* was coined to define a psychotic, violent reaction to AAS abuse. Many experts over time have stated that the incidence of roid rage is greatly exaggerated, concluding that it occurs very rarely. One of the difficulties, however, is that even if the base rate is extremely low, when there is an incident, it is often quite severe and gets a great deal of attention. The consequences are so significant that the low incidence rate is ignored, and the perception is that it is a more common occurrence than in fact it is. Research has associated elevated testosterone levels with increased aggressiveness. However, the research that shows that increase in violence is *caused* by steroids is equivocal. Scrutinizing the information, it is more accurate to say that AAS abuse is contributory toward violence rather than causative. The conclusions are based on the following:

- There are many AAS abusers who never become violent.
- Studies have not been able to control for the fact that people who endorse violence as a means to solve problems did not feel that way prior to AAS abuse.
- It is known that physical irritability is a precursor to aggressiveness. Steroid use often makes the user physically irritable, but not everyone becomes violent when they are irritable. Therefore, it is easier to conclude that AAS cause irritability, which in turn can lead to violence, than that AAS directly cause violence.
- Many medications and drugs have psychiatric side effects, but they appear very rarely. It is difficult to conclude, given the difficulties in conducting research on steroids, the likelihood of other factors contributing to a psychiatric reaction, the possible use of other illicit drugs, the personality variability of the abuser, and the accuracy of AAS dosages taken, that AAS alone are the causative agent in a roid rage reaction.

That is not to say that other drugs, legal or illegal, when abused by athletes cannot lead to violence. Most commonly, abuse of heroin and cocaine is self-selecting with athletes, meaning that athletes are less likely to develop severe addictions with either drug because if they do, it would interfere fairly quickly with their ability to perform as athletes. Therefore, even if these drugs were implicated with a heightened propensity for violence, athletes do not commonly abuse these drugs, so they are less likely to be the cause of violence by athletes.

Alcohol, on the other hand, owing to its disinhibitory properties, can make athletes who are prone to violent acting out more likely to indulge in violent behavior when under its influence. Athletes are not more vulnerable to alcohol's effects than nonathletes, but because of greater media attention, and perhaps because they may be more capable of doing damage, athletes who become violent when intoxicated are likely to find their names in the newspaper. Athletes who abuse prescription pills with similar disinhibitory properties, such as benzodiazepines (Ativan, Xanax, and Klonopin), may be at similar risk.

Alcohol may be the greatest contributor to violence at sports events, but this is more true of fans' unruly behavior while under its influence than of the behavior of athletes.

All the same, AAS abuse has been linked to athlete violence more often than any other illicit drug; however, the conclusion that AAS causes violence has not been supported.

Anger Management

As noted above, it is not anger per se that is the problem. Extreme levels of anger interfere with peak performance, and episodes of reactive aggression can lead to violence on and off the field. The goal, then, is not to ensure that athletes refrain from becoming angry but rather that they learn how to manage their anger and keep it at workable levels so that it can contribute to rather than sabotage performance.

Emotion Labeling

For athletes to become proficient at modulating their emotions, they need to become accustomed to identifying how they feel. Rarely does one verbalize an emotion when asked how one feels; usually, the question is responded to with "Okay" or "Fine." Emotion-labeling problems are commonplace in American society. Expanding athletes' vocabulary in describing how they feel is an important place to start, and this naturally expands to how their body reacts to emotion, specifically anger.

Education on Physiological Response to Anger

Because kinesthetic awareness is crucial to athletic success, athletes tend to be quite sensitive to changes in how their body feels. Thus, educating athletes about the bodily changes associated with anger (sympathetic nervous system arousal) enables them to relate easily to what is being described.

Expected physiological changes include increases in

- heart rate,
- breathing rate,
- blood pressure,
- muscle tension,
- sweating/perspiration, and
- the urge to urinate.

Helping the athlete understand that these signs are nearly identical to how their body reacts when they are anxious or nervous can sometimes normalize the experience as this is associated with the "butterflies in the stomach" seen in precompetitive anxiety. Remind the athlete that this is completely normal and is just a sign that his body is getting ready to do the things it has been trained for. Depending on the level of understanding of the athlete, one can either explain the physiology in detail or explain the "fight or flight" response as a programmed survival response and that these changes would help the athlete survive in the face of a threat.

The body does not realize that the athlete is getting ready to participate in a sport any more than it understands that you will not fight whenever you get angry. The spike in emotion coincides with your body getting ready to go.

This can be confusing for the athlete as the signs said to be produced by anger are also those that they normally see when participating in sports without an increase in anger. This discussion is important because it explains why it is so much harder to identify, let alone modulate, one's emotion during competition. To do this, one must become proficient in doing so in less stressful circumstances, outside the sports arena, first.

The physiological changes described above are said to be "all or none," meaning that when one is triggered by excitation, they all increase. Similarly, when one decreases, they all decrease. Identifying the bodily changes that one can directly control, namely, breathing rate and muscle tension, throws light on how to slow down the whole body and relax.

Last, by becoming more familiar with how their body feels when they are becoming increasingly angry, athletes can use the bodily cues as triggers to begin de-escalation techniques.

Arousal Management/De-Escalation

The skills most commonly prescribed to help athletes calm themselves are diaphragmatic breathing and imagery and visualization, but these are only two of several methods athletes can use.

Diaphragmatic breathing is a skill whereby an athlete can maximize oxygen intake by focusing on breathing deeply, flexing the diaphragm down and out, which results in the abdomen expanding outward as the lungs fill. The slow inhalation is followed by a significantly longer (some advise twice as long) exhalation through pursed lips. Repeating this process can help the athlete relax when tense or become more proficient at relaxing on demand.

Progressive muscle relaxation is another set of skills whereby the athlete is trained to control the tension of the muscles by alternatively, consciously flexing them, holding the tension and then slowly releasing it. This is done muscle group by muscle group and takes a good deal of time to gain proficiency in. Because the muscle tension, like the other sympathetic nervous system responses, is primarily all or none, the athlete can learn to relax the whole body by relaxing a single muscle group.

Another method of relaxation that is useful for athletes is *imagery and visualization*. Especially powerful is using imagery and visualization in conjunction with other relaxation techniques—for example, timing the athlete's diaphragmatic breathing with the ebb and flow of the ocean's waves, as they may be synergistic. First, the athletes can be guided through a relaxing scene, such as a quiet beachscape or any place athletes feel is particularly tranquil, where they can provide details of the sensory experience. There, the athletes are in charge of their visualization and are reminded of their ability to control their minds, their bodily response, and, ultimately, their ability to relax.

This can progress toward using imagery as a means to visualize the perfect sports performance and then, ultimately, a training ground where they can react to unforeseen obstacles and become prepared to "read and react." This works particularly well when anger is elicited early on, demonstrating its negative impact on cognitive processing and later, when the athlete becomes more proficient, remaining calm and able to solve problems despite potentially frustrating circumstances.

Music has also been found to have a profound impact on athletes' moods and arousal levels. Just as many athletes use music as part of their invigorating, precompetition routine, music can also be used to calm and center oneself, assisting with focus prior to competition.

All these tools, and others, can be used individually or in combination to assist athletes with increasing their emotional self-control, allowing them to adjust the "volume" of their emotions.

Trigger Recognition

By identifying the circumstances that are likely to lead to an athlete becoming angry, athletes can learn to recognize their triggers early and use their newly acquired arousal management tools to de-escalate rather than spontaneously react to a provocation. While these are often individualized, there are some triggers, called *direct triggers,* that are fairly universal and would lead most people to anger and to react forcefully. Direct triggers can be physical, such as being struck by another person, or they could be verbal. Verbal triggers could be insults, rudeness, cursing, accusations, unwelcome comments, or prejudicial comments.

Indirect triggers are more individualized and often are referred to as that athlete's "buttons" that can be pushed. They may be related to the athlete's insecurities, such as being called slow or weak, or may be denigrating comments about teammates or family members. It is a sign of greater personal strength to not react to these provocations as, often, the person's natural response is to react to the insult with a counterattack. By knowing themselves well, athletes are in a better position to recognize their triggers and compose themselves rather than respond in a way that is often as self-destructive as it may be dangerous to the provocateur.

Problem Solving

As mentioned earlier, frustration is a common precursor to anger and/or aggression. When athletes have difficulty solving problems, they are usually going to have more difficulty controlling their temper as well. Because problem solving becomes more difficult when the individual is very angry, there is the potential for an escalating cycle that ends badly. The whole situation gets further compounded when the athlete also has a hostility bias and has difficulty cognitively processing situations when angry. For this reason, teaching athletes basic problem-solving skills can go a long way toward keeping their emotions from interfering with their performance.

On a very basic level, the athlete must first be able to understand the factors that are involved in the problem that they face. This starts with a review of the 5 Ws and H—Who, What, Where, When, Why and How:

- Who is involved in the problem?
- What is the problem, and what details are important?
- Where is this occurring?
- When does it occur, and when do I need to solve this?
- Why is this a problem for me, and why is it difficult to solve?
- How did this become a problem, and how am I going to solve it?

Once the athlete is able to answer the associated questions, he or she can then generate a list of possible solutions. The athlete is encouraged to brainstorm solutions, and even if the problem is not sports related, using sports-based metaphors and hypothetical challenges can help the athlete feel increasingly confident of finding solutions to difficult problems. Often the athlete gets stuck because of difficulty generating multiple possible solutions, but with practice, the athlete will become more proficient in identifying several options that might help in solving the problem. This increasing self-efficacy in solving problems can help stave off frustration at not being able to find a solution easily.

Communication and Assertiveness Training

Once athletes get angry, their behavioral options, not to mention their word selection, become increasingly limited. Athletes can increase their personal strength by improving their communication skills, without which they will be more likely to become frustrated and less likely to reach their goals. For example, an athlete who is annoyed that he is not getting the amount of playing time he thinks he deserves is unlikely to persuade the coach to increase his playing time by yelling at the coach and demanding that she do as he says. Though it would be completely understandable for the athlete to be upset with the coach not meeting his requests, he would have a much better chance of meeting his objectives by calmly, in an even tone, asking to speak with the coach. He should then explain his frustration, why he would like more playing time, what he is willing to do to earn more playing time, and why it is in the team's best interest to give him more playing time; be receptive to the coach's feedback and respectful of the coach's authority; and leave the conversation poised and accepting of the outcome.

Good communication skills can improve with practice, and understanding how control of intense emotions can contribute to the process is crucial. Assertiveness training is a way to help athletes learn how to present themselves appropriately and stand up for their rights. It is important, however, to understand that although athletes have a right to be heard, their wishes do not have to be obeyed complied with by the coach or by anyone else. With their emotions in check, athletes are less likely to be frustrated when they are able to meet their goals through effective communication.

Cognitive Restructuring

People often become angry because of *cognitive distortions:* errors in the way they think, which lead them to see normal situations as provocative and have irrational ideas on how things *should* be. Athletes are no different in this regard, and teaching them to recognize that they may be perceiving things inaccurately and generating other views that may explain what they are seeing or experiencing can lead to improved emotional control and increased interpersonal relatedness. This skill is particularly useful with athletes who have the aforementioned "hostility bias," because it provides them an opportunity to challenge their previously existing cognitive tendencies that to them justified violence.

Prediction of Consequences

Even though there are plenty of things that happen that cannot be predicted (e.g., the outcome of a game or a match), there are also a great many that can. Many people do what they do in the heat of the moment and do not consider the consequences of their actions ahead of time. Athletes are often seen engaging in this type of behavior when they argue with a referee or umpire or get into a fight with another player. In the moment, they may think that they are justified in what they are doing, but would they still behave that way if they were fully aware of how important participating was to them and that they were risking being suspended and unavailable to help their team? Many people who engage in violent behavior claim that they could not control their impulses, but as you review their circumstances, if you change some details, you will find that most people control their impulses selectively, based on what they believe the outcome will be. Thus, teaching people to predict the consequences of their behavior can have a great impact on the decisions that they make in the moment.

It is important to remember that younger athletes will have more difficulty than those who are more mature in considering the longer-term consequences of their actions. That is why it is so important to teach these skills to youthful athletes as early as possible.

Mitch Abrams

See also Sport and Exercise Psychology

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Angioedema and Anaphylaxis

Exercise-induced anaphylaxis and angioedema (EIA) is defined as a systemic allergic reaction specifically triggered by exercise. It is different from exercise-induced urticaria, or "hives," in that there does not have to be an elevation in core body temperature for it to occur. Urticaria is often associated with EIA, though it is most often different in character from exercise-induced urticaria. While it is seen in people of all ages, it is more often seen in late adolescence and early adulthood. Up to half of the patients have a personal history of atopy and two thirds have a family history of atopy. Although there are thousands of cases documented, only one death has been reported; however, some cases may go undocumented.

EIA is triggered only by physical activity, unlike *cholinergic* (exercise-associated) *urticaria*, which is triggered by an increase in core body temperature. EIA can be triggered by any physical activities, but aerobic activities have a stronger association. Brisk walking, running, aerobic sports, and dancing are the most commonly cited triggers.

The natural history of EIA involves four phases, and it can vary in severity from person to person. Within several minutes of exercise initiation, patients undergoing an EIA attack experience warmth, fatigue, erythema (redness), and pruritus (itching). This is the prodromal phase. The attack may be abated if these symptoms are recognized by the patient. Then in the early phase, large hives develop, which coalesce to become angioedema, particularly around the face and extremities. If exercise is continued, anaphylaxis, with cardiac (hypotension, syncope), respiratory (wheezing, stridor), and gastrointestinal (colic, nausea, vomiting) symptoms, develops. This is the fully established phase, and it is in this phase that EIA is most life threatening and most differs from cholinergic urticaria. The attack can last from 30 minutes to 4 hours. A late phase may occur, which includes headache, fatigue, and warmth. This can last for 24 to 72 hours.

Certain conditions may increase the likelihood of EIA. Symptoms are more likely to occur in women during menstruation. Aspirin as well as nonsteriodal anti-inflammatory drugs (NSAIDs) can increase the likelihood of attacks, and they are the medications most often linked to EIA. Increased ambient temperature or exposure to known allergens may also increase the likelihood of attack.

There are several subtypes of EIA. Urticaria that typically develops with EIA is 10 to 15 millimeters (mm) in diameter, though 10% of patients have urticaria similar to that with exercise-induced urticaria, with small wheals 1 to 4 mm in diameter. This is known as *variant-type EIA*. In addition, other subtypes include *familial* and *food-dependent EIA*. Food-dependent EIA requires both food ingestion and exercise. Either one alone will not produce the symptoms. This is a Type 1 immune response, with positive skin-prick allergy tests for the food. Exercise occurs within 3 hours of food ingestion. Shellfish, celery, chicken, hazelnuts, apples, peaches, grapes, wheat, grain flour, and cabbage have been implicated as foods that are more likely to predispose to an episode of EIA.

The mechanism of EIA is still not fully understood. From skin biopsies and blood samples, however, it is known that there is mast cell degranulation and elevated histamine levels. It is postulated that EIA occurs when an antigen is bound by immunoglobulin-E (IgE) to release histamine from mast cells or basophils. Skin mast cells degranulate and release histamine, which is the most likely mediator of symptoms. Other vasoactive factors released include prostaglandin D2, leukotrienes C and D, platelet-activating factor, and bradykinin. Elevated tryptase levels have also been documented. Proteins, polysaccharides, and haptens can initiate an IgE response. Haptens are not immunologically active alone but become so after binding with a host protein. The complement pathway may also contribute. It is possible that exercise stimulates release of a particular antigen to stimulate IgE activation and mast cell degranulation. In food-dependent EIA, it is possible that food or exercise provides a necessary cofactor for the reaction to occur. NSAID-associated EIA may have a mechanism that involves alterations in arachadonic acid metabolism.

Diagnosis of EIA is best done with exercise testing. Diagnostic testing includes exercise testing under controlled conditions, with epinephrine, resuscitative equipment, and medical personnel at hand and an intravenous (IV) line in place. Exercise testing consists of running on a treadmill or using a stationary bicycle with progressive increases in intensity. Testing may need to be repeated on multiple occasions, as false negatives are likely to occur. For diagnosis, it may be necessary to attempt passive warming to rule out cholinergic urticaria.

The primary modality of treatment is education. The patient must know to stop exercise as soon as symptoms occur. It is also important to have subcutaneous epinephrine on hand (EpiPen) and to use it with any symptoms of EIA. Patients susceptible to EIA should always exercise or train with someone who knows their condition and can administer epinephrine if needed. It also may be wise to avoid exercise up to 24 hours after eating a potential food trigger or during menses and avoid NSAIDs as well as aspirin prior to exercise. It may be necessary to decrease the intensity of exercise and avoid intense exercise during very cold, hot, or humid weather or during high pollen counts. It is also important to identify any foods that may act as triggers if eaten several hours prior to the attack and eliminate them from the diet if possible. There has been very limited success with treatment with antihistamines.

Although EIA is a life-threatening condition, and somewhat unpredictable with regard to attacks, EIA patients can continue to exercise with strict adherence to the above principles. Fortunately, the majority of patients experience either stabilization or decrease of their symptoms with time, likely due to activity modification and avoidance of known triggers.

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See also Urticaria and Pruritus; Anaphylaxis, Exercise-Induced

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Ankle, Osteochondritis Dissecans of the

Osteochondritis dissecans (OCD) of the ankle is an acquired injury to the talus or ankle bone. Ankle OCD occurs in all kinds of athletes but especially in those who are involved in running or high-impact sports. Many athletes who develop OCD of the ankle are involved in multiple sports and participate in athletic activity for many hours every day. The OCD lesion occurs in the bone directly underneath the cartilage of the talus. It can be thought of as a stress fracture to a small area of the talus bone. After the injury, this area of bone is not strong enough to support the cartilage over top of it, and if the injury progresses, eventually the cartilage over top of the bone can crack. In most cases, OCD of the ankle occurs in athletically active children without a definite injury. In these cases, it is thought to be an overuse injury occurring from repetitive microtrauma to the bone. In some cases, a single major ankle sprain can cause an OCD of the talus.

Anatomy

The ankle joint is the space between the tibia (shinbone) and the talus (ankle bone). The ends of the tibia and talus are covered with cartilage that resembles the shiny smooth white end of a chicken bone. The cartilage provides a smooth low-friction surface for the ankle to allow the patient to flex and extend the ankle joint freely. The bone directly underneath the cartilage of the tibia and talus is called the subchondral bone. The purpose of the subchondral bone is to support the cartilage during walking and running. It is the subchondral bone that gets injured in OCD of the ankle.

Causes

OCD lesions occur in two common locations: (1) in the front (anterior), outer (lateral) aspect of the talus and (2) in the back (posterior), inside (medial) part of the talus. Anterolateral lesions tend to be shallow and can occur with one or more ankle sprains. Posteromedial lesions are more common and usually are deeper lesions that occur from repetitive trauma, causing a small stress fracture. Soccer, football, and basketball players often sustain multiple traumatic ankle sprains and may develop an OCD lesion. If the patient continues to be active, the injured bone will eventually lose its blood supply. At this point, it will no longer be able to support the cartilage over the top, and if the activity continues, the cartilage can crack and break loose.

Symptoms

OCD of the talus can occur in athletes of all ages, although it most commonly occurs in highly active athletes aged 13 to 14 involved in soccer, basketball, football, or other high-impact sports. Patients complain of aching ankle pain, which becomes worse when running or sprinting. In some patients, but not all, there may be a history of multiple major ankle sprains. The pain is often located at the inner or outer aspects of the ankle, depending on the location of the OCD lesion. Pain may be severe enough to cause a limp. If the overlying cartilage is cracked and injured, the ankle will often swell, and mechanical symptoms such as catching or locking may be noted. In 10% to 25% of the cases, both the ankles will have an OCD lesion.

Diagnosis

An active athlete playing multiple high-impact running sports for many hours every day who presents with ankle sprains, swelling, and pain may have an OCD of the talus. On physical exam, the ankle joint is carefully inspected for signs of swelling. The front and back of the ankle are palpated for tenderness. The ankle is flexed and extended to see if either of these maneuvers causes pain. If OCD of the ankle is suspected, both ankles must be examined and X-rays must be obtained.

Depending on the size and location of the OCD lesion, it may or may not be visible on the X-ray. When visible, it appears as a small round crack in the subchondral bone (see white arrow in X-ray). The X-rays help determine the size and location of the lesion. If the growth plate of the tibia bone is visible on the X-ray, it indicates that the child is still growing.

The cartilage of the ankle cannot be captured by an X-ray. Therefore, when an OCD lesion is suspected, a magnetic resonance imaging (MRI) scan of the ankle may be obtained. The MRI scan is used to determine if the cartilage over the lesion is intact or cracked. If the cartilage is cracked, there will often be joint fluid underneath the lesion, which can be seen well on the MRI scan.

OCD of the ankle is generally classified as "stable" or "unstable." Stable lesions involve only the subchondral bone; the overlying cartilage is not broken. In unstable lesions, the overlying cartilage is cracked. Making this determination is important because stable lesions tend to heal well with rest and activity restriction. Unstable lesions do not heal as well and if left untreated can completely break off, forming a "loose body."

Treatment

The two most important factors involved in planning treatment for an OCD of the ankle are the age of the athlete and the stability of the lesion. In general, most stable lesions in children who are still growing heal without surgery. For partially unstable lesions in children with open growth plates or for stable lesions in patients who are already grown, a short period of nonsurgical management is often attempted. However, if the OCD lesion does not heal after 3 to 6 months, surgery is recommended. Unstable lesions and most lesions in patients with closed growth plates are treated with surgery.

OCD of the Talus (white arrow)

Source: Photo courtesy of Dennis E. Kramer, M.D.

Nonsurgical Treatment

The most important principle for nonsurgical treatment of OCD of the ankle is to stop the repetitive activities that cause the pain. This means that the patient must be removed from most sports that involve running and jumping. Nonimpact activities such as swimming and low-resistance cycling are encouraged. Compliance with these measures is often difficult in this highly active patient population. In addition, some physicians recommend using crutches and/or an air cast boot or short leg cast to immobilize the ankle.

The initial treatment phase of rest, possibly combined with crutches and immobilization, usually lasts for about 6 weeks. At this time, the patient's pain should be improved, and the crutches and boot or cast can be discontinued. Physical therapy is initiated, focusing on ankle range of motion and strengthening. At periodic follow-ups, the physician ensures that the patient's symptoms are improving and may follow the appearance of the lesion with serial X-rays. Full healing of the lesion can often take anywhere from 3 to 12 months. Some physicians will obtain a repeat MRI scan after 3 to 6 months to assess the healing of the lesion. Return to sports can take anywhere between 3 and 12 months and occurs when the athlete is painfree and the lesion has shown signs of healing.

Surgery

Surgery is recommended for unstable OCD lesions and for lesions that do not heal after an appropriate time period of nonsurgical management. Surgical intervention commonly involves ankle arthroscopy, although a larger incision may be necessary. During arthroscopy, the surgeon will directly look at and feel the cartilage over the top of the lesion. Depending on the appearance and feel of the cartilage over the lesion, the surgeon will decide how to proceed.

In some cases, the cartilage over the lesion will appear normal, with no cracks, but will feel like a softened mass. In these cases, the surgeon may drill tiny holes through the cartilage and across the OCD lesion. This technique is called *transarticular drilling*. The idea is to stimulate the underlying subchondral bone to bleed, which will allow it to heal. If the lesion is very large or if the cartilage is partially cracked, the surgeon may also perform internal fixation. In these cases, metal or bioabsorbable screws or bone pegs are placed across the lesion to provide stability and compression.

In some cases, the cartilage over the lesion will be completely destroyed or will have broken off to form a loose body. In these cases, the surgeon will often just remove the cartilage over the lesion or remove the loose body. The underlying subchondral bone will then be exposed. The surgeon may then elect to perform a *microfracture procedure,* in which a tiny pick is used to create small holes in the subchondral bone. These holes will bleed, and a blood clot will eventually form over the OCD lesion. Over time, the blood clot can repair the lesion with a fibrous form of cartilage. Newer cartilage transplantation techniques are often reserved for patients who have already had the microfracture procedure done but still have pain.

After Surgery

After surgery, the patient is placed in a short leg cast or air cast boot and is required to use crutches. Depending on the surgeon's preference and the procedure employed, crutches and boot or cast may be used for 6 weeks or more after surgery. Ankle motion is slowly increased over time. Physical therapy is often initiated to help the patient regain ankle motion and strength. The patient is not allowed to resume sports activities until the lesion is felt to have healed, which may take between 3 and 12 months. Athletes involved in high-impact cutting sports may benefit from wearing an ankle brace after surgery.

Dennis E. Kramer

See also Elbow, Osteochondritis Dissecans of the; Knee, Osteochondritis Dissecans of the; Sports Injuries, Surgery for

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Ankle Fracture

Ankle injuries are among the most common injuries in sports. Approximately 15% of all ankle injuries involve fractures of the ankle. Sports that may put an athlete at risk include basketball, soccer, football, softball, and baseball, among others. Any sport that involves cutting or abrupt changes in direction may put undue stress on the supportive structures around the ankle, resulting in failure and, at times fracture.

Anatomy

The ankle joint is an articulation composed of three bones—the tibia, the fibula, and the talus. The bones are covered in cartilage at their ends, allowing for painless gliding movement of this *ginglimus* (hinge)-*type joint*. To enhance the stability of the ankle joint, the body has a number of ligaments that form attachments between the bones. They are the deltoid ligament complex, anterior talofibular ligament, calcaneofibular ligament, posterior talofibular ligament, and anterior and posterior tibiofibular ligaments.

The joint is somewhat like a saddle over the talus. Furthermore, the talus is wider anteriorly (in the front) than posteriorly (in the back), and as the ankle dorsiflexes (moves away from the ground), there is more bony contact in the joint, rendering it more stable.

Causes

As the ankle encounters a significant enough force, the structures that it consists of will fail in a predictable pattern based on the position of the ankle and the forces applied at the time of injury. The ankle may roll in or out or may be twisted from side to side. Last, direct impact from jumping from a height may cause the ankle to break (see Figure 1).

Symptoms

The symptoms of an ankle fracture are variable depending on the mechanism, the location of the fracture, and the severity of the injury. Pain may be directly over the break or may be referred to another area of the foot or lower leg. Swelling will be present over the area of soft tissues that have been stretched or torn. There may be a collection of blood in the area or in the joint itself, which is called *hemarthrosis*. As time passes, the blood that pools in the ankle may settle in the skin, causing color changes. If swelling is significant enough, there may be enough pressure on the nerves to cause numbness or tingling. Bearing weight through the ankle will generate extreme pain.

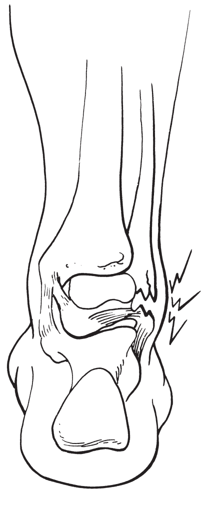

Figure 1 Example of an Ankle Fracture

Note: Ankle fractures usually affect the bottom end of the fibula on the outer side of the lower leg and usually occur in the same way many inversion sprains do; the athlete rolls over on the ankle, and the body's momentum breaks the bone.

Diagnosis

Diagnosis always begins with the history and a physical examination. The history commonly includes a fall with twisting of the ankle followed by immediate pain and swelling. The ankle is palpated for tender areas. Neurovascular status is assessed. This includes palpation of the dorsalis pedis and posterior tibial pulse, as well as assessing the sensation over the top and bottom of the foot and the first web space. Movement of the ankle and toes may be attempted but is often very painful. Breaks in the skin or frank bleeding raises the possibility of an open ankle injury, previously referred to as a *compound fracture*. These injuries are more serious because they pose an increased risk of infection and generally involve more energy.

Next, an X-ray examination is usually performed, which generally also includes a joint above and below the zone of injury. This would include the knee, tibia/fibula, and foot. Ankle X-rays should include three separate views, the anterior-posterior, lateral, and mortise. The *mortise view* is a 15° to 20° internal rotation view that shows the joint surface without the overlap of the tibia and fibula. The clear space between the tibia, talus, and fibula should be equal on the top as well as on both sides. Incongruency denotes not only fracture but also displacement of the talus and possible syndesmosis injury.

A number of classification schemes exist for ankle fractures. These are somewhat academic, but familiarization with them helps when physicians/ trainers are describing injuries via phone. The *Weber classification* describes the level of a fibula fracture. The *Lauge-Hanson classification* describes the position of the foot and the forces applied at the time of injury, which produce predictable patterns of injury. More important, a classification that truly directs treatment is the *Gustilo-Anderson,* which is applied to all fractures, describing the nature of open fractures and the amount of soft tissue involvement.

Treatment

Initial treatment generally takes place in the emergency department. For most closed low-energy ankle fractures that occur in sports, management begins with closed reduction and splinting. *Closed reduction* refers to "setting" the ankle when the fracture has displaced or moved from the normal bony alignment. Often this is preceded by adequate sedation and analgesia. Splints are usually made of plaster and do not entirely encompass the circumference of the leg to allow for swelling, which usually ensues over the first 48 to 72 hours. With *r*est, *i*ce, *c*ompression, and *e*levation (RICE treatment) over the first 10 to 14 days, swelling resolves, and further treatment plans are made. The patient should adhere to strict non–weight bearing until a reassessment is made. Prescription-strength pain medications are generally given after the initial evaluation.

Nonsurgical Treatment

At this point, patients usually follow up in the physician's office, and minimally displaced fractures, or those that have not moved far, can be placed in a short leg cast for another 4 to 6 weeks. Serial X-rays will be required to monitor both the healing status of the bone as well as the alignment. Casts are made of fiberglass and are of lighter weight than fiberglass splints. They are circumferential and should be molded to the patient's leg with certain forces applied to hold the alignment of the ankle appropriately. The ankle should be at 90° once the cast is complete to prevent stiffness following cast removal. The amount of time a patient is kept non–weight bearing depends on the stability and the injury pattern. The ankle may be transitioned to a CAM (controlled ankle motion) walker for progression to full weight bearing. Once the fracture is healed and weight bearing has begun, physical therapy focuses on regaining strength and range of motion of the ankle and lower extremity. The lack of use of the leg will result in atrophy of the muscles and stiffness of the joint; this must be overcome before the athlete returns to play, so as to minimize the risk of reinjury.

Surgery

Surgical indications, simply put, include significant angulation or displacement of the fracture, an incongruent joint, or a fracture that involves the joint surface. Other indications include open fractures, where the bone has been exposed to the outside environment, increasing the risk of infection. Surgery should be delayed until the swelling of the soft tissues around the ankle has resolved. Plates and screws are commonly used to stabilize the fracture fragments. Surgical planning includes determining the type of fixation, the size and number of plates and screws that will be needed, and the anatomic approach that will be used. Soft tissues are dissected in internervous and intermuscular planes to expose the bony fragments. The fracture site is reduced, or realigned, under direct vision and with the assistance of X-ray fluoroscopy. Hardware is then placed to stabilize the fracture and hold it in place until it heals. In many individuals, there is a paucity of soft tissue coverage over the ankle region, and plates and screws may become bothersome over time, requiring removal. For the most part, however, the plates and screws are left in place even after the fracture has completely healed. Following surgery, the ankle is placed again in a splint until swelling has resolved. A cast is then placed at about 10 to 14 days postoperatively, when the soft tissue swelling has resolved.

Return to Sports

Bony healing takes place over the 6 weeks following surgery or casting. Ligamentous healing may take several more weeks. Most daily activities and normal ambulation without a limp may be possible within 3 to 4 months. Return to sports at the same level is often a 9- to 12-month process, and overall recovery may take up to 2 years. As the athlete returns to his or her respective sport, AFOs (ankle-foot orthotics) are often used for additional support and can be weaned as strength, mobility, and confidence return.

Andrew R. Duffee and Jeffrey A. Guy

See also Ankle Injuries; Ankle Support; Musculoskeletal Tests, Ankle; Podiatric Sports Medicine

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Ankle Impingement

Ankle impingement, generally speaking, is a painful limitation to full range of motion of the ankle joint. Most often the inciting factor is trauma, usually an ankle sprain. However, infectious, rheumatologic, degenerative, and even congenital causes are also possibilities. The injury is one that is chronic in nature and is often seen in young athletes with repetitive injures, or repetitive motions in their respective sports.

Anatomy

The ankle joint is hinged, or a *ginglimus joint*. It is an articulation composed of three bones—the tibia, the fibula, and the talus. The cartilage that covers the surface of the joint allows for painless movement of dorsiflexion and plantarflexion. Dorsiflexion is movement of the foot toward the head, and plantarflexion is movement of the foot toward the floor. The ankle has many ligaments that help enhance the stability of the joint. These include the deltoid ligament complex, anterior talofibular ligament, calcaneofibular ligament, posterior talofibular ligament, and anterior and posterior tibiofibular ligaments. The names indicate the bone from which the ligaments originate and insert. The joint is shaped like a saddle over the talus. The talus is a trapezoid and is wider in the front than in the back. It is because of this shape, that the ankle is more stable when dorsiflexed (moves away from the ground).

Causes

Anterior impingement is often caused by forced dorsiflexion and activities that incorporate that movement such as soccer or ballet. Bone spurs may develop on the anterior tibia and talus, causing subsequent pain.

Anterolateral impingement is caused by repetitive inversion-type ankle sprains. This causes synovitis or a scar that limits ankle motion in that plane. The repetitive sprains cause overgrowth of tissue in the area, which then impinges on the cartilage surfaces, inducing pain.

Posterior impingement results from the posterior tissues becoming impinged following repeated plantarflexion (downward motion of the ankle). This causes repetitive microtrauma, resulting in inflammation and overgrowth of certain tissues. Activities such as dancing, kicking, gymnastics, or downhill running may predispose an athlete to this condition.

Symptoms

The patient will complain of pain as the primary symptom. The pain will be exacerbated by the movement that corresponds with the type of impingement. Anterior impingement will be worsened by forcing the ankle toward the head or lunging forward with the foot flat on the floor. These patients will also complain of stiffness in their ankle. Anterolateral impingement will cause pain along the anterior talofibular ligament and lateral gutter. They will often have a poor sense of where their ankle is in space, and their symptoms will seem worse with cutting activities. Posterior impingement is a more difficult diagnosis to make, but again the complaint will be pain or catching with push-off or forced plantarflexion.

Diagnosis

The diagnosis always begins with a thorough history and physical examination. Important questions to ask are as follows: When did the pain begin? Is it constant, or does it come and go? Is there a specific injury or trauma that occurred? Where specifically is the pain, and is there a movement that exacerbates it? (The athlete should try and localize the pain with a single finger.) Are there any associated catching, clicking, or mechanical-type symptoms? Has any treatment been tried that makes the pain better or resolves it? The physical exam begins with visual inspection for any obvious swelling or deformity. The ankle is palpated for tender areas. Neurovascular status is assessed. This includes palpation of the dorsalis pedis and posterior tibial pulse as well as assessing the sensation over the top and bottom of the foot and the first web space. Movement of the ankle and subtalar joint is assessed. This includes dorsiflexion, plantarflexion, inversion, and eversion. The patient with impingement may complain of pain at the extreme of one of these motions.

X-rays should include images of the joints above and below the injury. In the case of ankle impingement, this will generally include the knee, tibia/fibula, and foot. Ankle X-ray series should always include the anteroposterior, lateral, and mortise views. Most often these will result in normal findings. Subtle abnormalities that may be appreciated include an *os trigonum*, a small bone in the posterior ankle, present in about 7% of the population, which may contribute to posterior impingement. Spurs may be present on the talus or tibia anteriorly in those with anterior impingement. Lateral X-ray of the ankle in a forward lunging position may demonstrate bone-on-bone impingement. Magnetic resonance imaging (MRI) is helpful in identifying soft tissue involvement and is overall the more useful imaging technique.

Treatment

The goal of treatment is to relieve pain and resolve inflammation so that the athlete may return to sports at full strength. Generally, treatment begins with standard rest, ice, anti-inflammatories, bracing, orthotics, and physical therapy. Nonsteroidal anti-inflammatories are very useful in relieving inflammatory pain such as in the case of impingement. Ibuprofen and naproxen are two of the most commonly used over-the-counter medications. Other prescribed anti-inflammatories include sulindac and ketoprofen.

Nonsurgical Treatment

In addition to the nonsurgical measures listed above, other modalities that may be useful include electrotherapy, injections, and reevaluation of techniques in areas such as dance or ballet. Injections may be helpful as a diagnostic tool as well, helping to determine whether the pain is located in the ankle joint or the subtalar joint.

Surgical Treatment

Arthroscopic excision of the inciting tissue or ossicle is the surgical treatment of choice. Occasionally, open treatment may be required to achieve a thorough debridement. Generally, athletes are advised *r*est, *i*ce, *c*ompression, and *e*levation (RICE treatment) over the first week or two until the sutures are removed. They are allowed to bear weight as tolerated through the postoperative course. Rehabilitation focuses on strength, range of motion, and sport-specific goals. Operative intervention is successful in 80% or more patients.

Return to Sports

Generally, the athlete may be able to return to sports when he or she has regained full strength and painless range of motion. Most often these goals can be met at about the 5- or 6-week mark. Sport-specific training is especially important in dance and ballet, where technique may have been the root cause of the problem. Another important goal is proprioception, or the sense of where the joint is in space. This is often lost with impingement syndrome and can be improved on with aggressive physical therapy.

Andrew R. Duffee and Jeffrey A.Guy

See also Ankle Injuries; Ankle Instability; Ankle Instability, Chronic; Ankle Sprain; Ankle Support

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Ankle Injuries

Among athletes participating in sports, injuries to the ankle are very common. Ankle sprains alone account for about 25% of all sports-related injuries. Ankle injuries are particularly common in running and jumping sports such as volleyball, basketball, and soccer. In basketball, 20% to 50% of injuries involve the ankle; 17% to 29% of all soccer injuries are ankle injuries. Inversion (foot turned in) injuries are much more common than eversion (foot turned out) injuries because of the weakness of the lateral ligaments and the relative instability of the lateral ankle. Eversion injuries are uncommon. Most ankle injuries can be successfully treated conservatively with *p*rotection, *r*est, *i*ce, *c*ompression, and *e*levation (PRICE) and appropriate rehabilitation.

Anatomy

The ankle is a simple hinge joint consisting of the tibia, fibula, and talus. These three bones articulate at the ankle (talocrual) joint and are stabilized by ligaments and an interosseous syndesmosis. The tibia is the main weight-bearing bone in the lower leg. The tibia extends into the medial malleolus, which provides medial bony support for the ankle mortise. The distal tibia and fibula form the inferior tibiofibular joint, which allows for rotational movement essential for barefoot walking and running. The tibia and fibula create a boxlike mortise, in which the talus rests. The talus is wider anteriorly and narrower posteriorly, providing bony stability when the joint is in neutral position as the wider part of the talus is locked securely in the joint. Movement at the ankle joint is predominantly dorsiflexion (toes up) and plantarflexion (toes pointed down).

The third joint of the ankle, the subtalar joint, comprises the talus and the calcaneus and is separated into an anterior and posterior articulation divided by the sinus tarsi. The subtalar joint provides shock absorption, allows the foot to adjust to uneven ground, and allows the foot to remain flat on the ground when the leg is at an angle to the ground. Inversion (foot turned inward) and eversion (foot turned outward) of the ankle occur at the subtalar joint (Figure 1).

There are three muscle compartments of the ankle: anterior, lateral, and posterior. The boundaries between these compartments are formed by the interosseous membrane and the anterior aspect of the tibia. The anterior compartment consists of the extensor hallucis longus, extensor digitorum longus, and anterior tibialis muscles, which act primarily to dorsiflex the ankle. The anterior tibialis

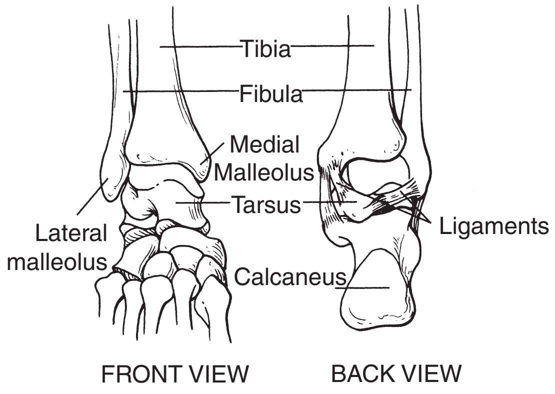

Figure 1 Ankle Anatomy

Notes: The ankle is stabilized by the lateral ligament complex: the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and the posterior talofibular (PTFL) ligament. The ATFL is the primary ligamentous support protecting the ankle from inversion stress and is the most commonly injured ligament in the body. It originates at the anterior aspect of the lateral malleolus, runs almost parallel to the axis of the foot, and attaches to the talus anteriorly. The CFL is stronger than the ATFL; it runs from the tip of the lateral malleolus to the lateral surface of the calcaneus. The PFTL runs from the posterior aspect of the lateral malleolus to the posterior talus. Medial support is provided by the deltoid ligament, a fan-shaped structure emanating from the distal tibia. The deltoid ligament consists of a superficial layer, running from the medial malleolus to the medial aspect of the calcaneus, and a deep layer, originating from the medial malleolus and attaching to the talus. Anterior fibers of the deltoid ligament attach to the talus and navicular; posterior fibers attach to the talus. The high ligaments are the anterior inferior tibiofibular ligament, posterior inferior tibiofibular ligament, and interosseous syndesmosis.

attaches to the first metatarsal and cuneiform and inverts the foot. The lateral compartment consists of the peroneus longus and brevis muscles, which evert the foot. The peroneus brevis attaches to the base of the fifth metatarsal; the peroneus longus crosses the sole of the foot and attaches to the first cuneiform and the base of the first metatarsal. The posterior compartment has superficial and deep groups. The superficial group is the triceps surae and comprises the gastrocnemius, soleus, and plantaris. The deep group consists of the flexor hallucis longus, flexor digitorum longus, and tibialis posterior muscles. These muscles plantarflex the ankle, flex the toes, and invert the foot.

Innervation of the ankle is supplied primarily by the sciatic nerve. The dorsiflexors are innervated by the common peroneal nerve. The muscles of the posterior compartment are innervated by the tibial nerve. The peroneal muscles are innervated by the superficial peroneal nerve. The muscles of the anterior compartment are innervated by the deep peroneal nerve.

In pediatric athletes, open growth plates in the distal tibia and fibula predispose both children and adolescents to growth plate fractures not seen in adults. Children are also more likely to have avulsion fractures because the attachment areas of ligaments are relatively weaker than the ligaments themselves.

Evaluation of Injuries

Details of Injury

Ankle pain in an athlete can be from an acute or a chronic injury. The mechanism of injury, specifically whether it was an inversion or eversion injury, can suggest which structures have been damaged. The onset of pain and the ability to weight bear immediately after an injury can also help determine the severity of the injury. Pain that increases with continued activity suggests a ligamentous injury rather than a fracture. The location of pain, swelling, and bruising can also help suggest the particular injury. The degree of swelling, bruising, and disability may indicate the seriousness of the injury.

For chronic injuries, it is important to determine what treatment has already been instituted: medication history, PRICE (*p*rotection, *r*est, *i*ce, *c*ompression, and *e*levation), duration of restricted weight bearing, taping/braces, or physiotherapy. It is also important to ascertain if there is a previous history of injury.

It is important to assess the athlete's sport, position, and level of competition and what stage the athlete is in his or her season or training.

Physical Findings

Injuries of the ankle may result in swelling, bruising, or deformity of the ankle. The athlete may walk with a limp or be unable to weight bear.

Range of motion of the ankle may be decreased in all directions. Pushing the foot outward against resistance may cause pain behind the lateral malleolus if there has been an injury to the peroneal tendon. The point of maximal tenderness to palpation can help localize the structures injured.

There are some special tests that can help diagnose ankle injuries, such as the anterior drawer test, lateral talar tilt, proprioception or balance, and hopping and lunge test. The anterior drawer test assesses for stability of the lateral ankle. One hand is used to stabilize the lower leg. The ankle is slightly plantarflexed and grasped by the heel. Pressure is exerted upward, and the degree of excursion is compared with that of the uninjured ankle. The talar tilt test assesses the integrity of the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and the deltoid ligament. One hand is used to stabilize the lower leg; then the ankle is grasped by the heel, and medial and lateral movements of the talus and calcaneus in relation to the tibia and fibula are noted. Proprioception is assessed by having the athlete stand on the injured leg with eyes closed and comparing the balance with that on the uninjured side. Functional assessment is made by having the patient hop on the injured side and perform a lunge to determine the degree of dorsiflexion.

"High" ankle sprains involve injuries to the anterior tibiofibular ligament or the syndesmosis. Tests that help diagnose high ankle sprains include the squeeze test and the external rotation test. The squeeze test is performed by compressing the proximal tibia and fibula between the examiner's hands. Pain elicited in the syndesmosis is considered a positive test. The external rotation test is performed by stabilizing the lower leg with one hand while abducting the foot with the other hand. A positive test reproduces pain in the syndesmosis.

Investigations

Palpation to determine the maximal point of tenderness can help determine whether investigations are necessary in ankle injuries. If the maximal point of tenderness is bony, X-rays should be obtained. The Ottawa Ankle Rules can help determine the need for X-rays (Figure 2).

Osteochondral (bony) injuries may not be apparent on X-rays. If an athlete with an ankle injury is not progressing as expected, or if there is persistent significant pain and disability, other investigations should be done, such as bone scan, ultrasound, computed tomography (CT), or magnetic resonance imaging (MRI). CT provides superior bony detail, whereas MRI provides better definition of soft tissues, such as ligaments and tendons.

The Ottawa Ankle Rules

An ankle X-ray series is necessary only if there is pain in the malleolar zone and any one of the following:

1. Bone tenderness at the posterior edge or tip of the lateral malleolus
2. Bone tenderness at the posterior edge or tip of the medial malleolus
3. Inability to weight bear both immediately and in the Emergency Department

A foot X-ray series is necessary only if there is pain in the midfoot zone and any of the following:

1. Bone tenderness at the base of the fifth metatarsal
2. Bone tenderness at the navicular bone
3. Inability to weight bear both immediately and in the ED

Figure 2 The Ottawa Ankle Rules

Types of Injury

Table 1 lists the types of ankle injuries.

Table 1 Ankle Injuries

Common	*Uncommon*
Lateral ankle sprain	Medial ankle sprain
Fractures	Osteochondritis dissecans of talus
Peroneal tendinitis	Peroneal subluxation
Accessory navicular	Chronic instability of the ankle
Apophysitis	Posterior tibial tendinitis
	Anterior-posterior impingement
	Reflex sympathetic dystrophy
	Syndesmosis injuries (high ankle sprain)

Prevention of Injury

Ankle injuries can be prevented by ensuring good overall fitness and conditioning. Athletes should endeavor to maintain an appropriate weight with proper nutrition and healthy lifestyle behaviors.

A preparticipation assessment at the start of an athlete's season can elicit any injuries or muscle imbalances that may predispose to injury during the season and allow for appropriate rehabilitation in the preseason. The proper protective equipment for the sport should be worn, properly maintained, and replaced as necessary. Ankle taping or supportive bracing should be used as necessary. Prior to practices and games, athletes, coaches, and trainers should "walk the field" to identify any potential hazards, such as uneven playing surfaces or debris on the playing surface. Practices should emphasize appropriate warm-ups and specific skill drills, such as balance training, cutting, jumping, and landing, to improve strength, flexibility, and neuromuscular control.

Education is vital to help prevent injuries. Athletes, parents, trainers, and coaches should know basic injury care and when to seek medical attention. It is important that injuries are promptly identified and rehabilitated to prevent their worsening.

Return to Sports

Return to sports following an injury can be tricky, but basically, the athlete should be able to weight bear, run, jump, and do everything necessary for his or her sport without pain. Depending on the injury, it may be necessary for the athlete to be non–weight bearing for a period of time to allow healing to occur. During this time, the athlete can participate in non–sport-specific aerobic activity, such as swimming and stationary biking, to help maintain cardiovascular conditioning and increase blood flow to the extremities. Physical therapy may be necessary to improve range of motion, strength, and balance, as well as reduce swelling.

Once the athlete is able to fully weight bear and is comfortable with the activities of daily living, he or she can proceed through a functional return-to-sport protocol (Table 2), under the direct supervision of a certified athletic trainer, physiotherapist, or physician. The athlete should not experience any sharp pain when progressing to more advanced tasks; mild discomfort is acceptable. If pain increases, the athlete should go back to the previous step for 2 to 3 days before

Table 2 Some Examples of a Functional Return-to-Sport Protocol

1. Toe raises, both legs together: 1–3 sets, 15 repetitions
2. Toe raises, injured leg alone: 1–3 sets, 15 repetitions
3. Balancing on the injured leg: 1–3 sets, 30 seconds in duration
4. Walking at fast pace: 1–3 times, 50 yards (yd; 50 yd = 45.7 meters) each
5. Jumping on both legs: 1–3 sets, 10 times each
6. Jumping on the injured leg: 1–3 sets, 10 times each
7. Easy-paced, straight-line jogging: 1–3 times, 50 yd each
8. Sprinting (half speed, quarter speed, and full speed): 1–3 times each, 50 yd each
9. Jogging, straight and gradual curves: 2–3 laps around the field, court, or track

trying to advance again. Athletic taping or a foot orthosis may be necessary for the remainder of the sport season to prevent reinjury. The athlete may be able to return to a less demanding player position sooner than his or her typical position.

In sports such as cross-country, track, and running, the athlete can gradually advance to the desired distance at this point. For more demanding sports (football, soccer, basketball, baseball, tennis), the athlete needs to advance to more sport-specific drills, such as the following:

1. Running figure eights (half speed, quarter speed, full speed): 1–3 times each
2. Crossovers, 40 yards (yd; 40 yd = 36.58 meters): 1–3 times to the right and left
3. Backward running (back peddling): 1–3 times, 40 yd each
4. Cutting (half speed, quarter speed, full speed): 1–3 times
5. Sport-specific drills
6. Return to sport

Laura Purcell

See also Ankle Instability, Chronic; Ankle Sprain; Ankle Support

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Ankle Instability

Ankle instability is a term that describes patients' perception that their ankle is "giving way." Laxity of the ankle ligaments is found on examination, caused by acute ankle sprain or recurrent injury (chronic ankle instability). Ankle instability can involve the lateral or medial ankle ligaments. Ankle sprains are a common sports-related injury, accounting for up to 40% of all athletic injuries. Sprains are particularly prevalent among basketball, soccer, and football players and account for 10% of emergency department visits.

Anatomy

The lateral ankle ligament complex is composed of the anterior talofibular ligament (ATFL), the calcaneofibular ligament (CFL), and the posterior talofibular ligament (PTFL). The ATFL runs from the distal fibula to the talar neck and is the primary restraint to anterior displacement on the tibia. It functions to restrict ankle inversion, particularly in plantarflexion. It is the weakest lateral ankle ligament and is most commonly involved in lateral ankle sprains. The CTFL is the primary ligamentous restraint to ankle inversion in dorsiflexion and is injured in at least half of all lateral ankle sprains. It runs from the distal fibula to the lateral calcaneus. The PTFL extends from the posterior fibula to the lateral talus. This ligament is injured in 10% of lateral ankle sprains.

The medial ankle ligament (deltoid ligament) is the strongest ankle ligament. It arises from the medial malleolus of the tibia and inserts at multiple sites, including the calcaneus, the talus, and the spring ligament of the foot.

Dynamic stability is provided by the peroneal muscles on the lateral side of the ankle. These muscles function as evertors. Medially, the tibialis posterior muscle aids in hindfoot inversion and medial ankle stability.

Etiology

The position of the ankle at the time of the sprain determines the pattern of ligament injury. Lateral ankle sprains result from inversion and internal rotation of the foot on an externally rotated leg. In plantarflexion, the ATFL is usually injured in isolation. In dorsiflexion, both the ATFL and the CFL may be injured.

Medial ankle ligament injuries are much less common than lateral ankle injuries. Isolated medial injuries typically occur as a result of excessive hindfoot eversion, as in dancing, landing on an uneven surface, or running down stairs. Often patients are predisposed to injury by valgus alignment of the hindfoot and/or tibialis posterior tendon dysfunction.

In some chronic ankle injuries, patients can present with both medial and lateral ankle instability.

Chronic ankle instability is characterized by persistent pain, recurrent sprains, and repeated instances of the ankle giving way. While the etiology of chronic instability is multifactorial, a history of primary ankle sprains is a major contributor. Chronic ankle instability can arise as a result of pathologic laxity, degenerative changes, strength deficits, impaired proprioception, and/or poor neuromuscular controls. (See the entry Ankle Instability, Chronic.)

History

Acute ankle sprains typically present with an inversion-type injury associated with sports participation, a slip and fall, or other traumatic event. Patients complain of pain, stiffness, and swelling at the ankle, worsened by weight bearing. Depending on the severity of the injury, the patient may be unwilling to weight bear on the limb.

Chronic ankle instability can present as a series of multiple ankle sprains, "giving way" episodes, deformity, and/or pain.

Physical Examination

On examination of the acutely sprained ankle, one notes ecchymosis and edema about the injured soft tissues, tenderness about the bony and ligamentous landmarks, and limited ankle range of motion due to pain. In lateral ankle injuries, the ATFL and CFL are most often tender, whereas tenderness over the deltoid ligament is characteristically present in medial instability.

Dynamic stability is assessed by a strength test of the peroneal muscles (resisted eversion of the foot) and the tibialis posterior (ability to complete a single limb heel rise).

Ligament laxity is assessed by means of two special tests: (1) the *anterior drawer test* and (2) the *inversion stress test*. The anterior drawer test assesses the ATFL for laxity as the examiner passively translates the talus anteriorly on the tibia. The examiner uses the inversion stress test to look for laxity of the CFL by passively inverting the hindfoot on the tibia. Both tests use the contralateral uninjured limb as a baseline for comparison. Excessive motion is considered a positive result. In the acutely injured ligament, these tests can be painful, helping to confirm the diagnosis.

The examination of an ankle with chronic instability further requires an assessment for contributing deformity about the lower extremity. These include excessive heel valgus and a planovalgus "flat" foot (for medial injuries) or cavus-type deformities with hindfoot varus and/or plantarflexion of the first ray (for lateral injuries). Examination for the presence of generalized ligamentous laxity should be carried out, as well as ruling out other pathology that may mimic chronic instability (ankle or hindfoot fractures, arthritis, tarsal coalition, osteochondral injuries, peroneal tendon injuries, etc.). In chronic injuries, laxity of the ankle ligaments may be more easily demonstrated due to the lack of an acute injury, while other clinical signs may be subtler, with little or no ecchymosis and edema limited to a joint effusion.

Imaging

The indications for X-ray evaluation in the case of an ankle sprain are well-defined by the Ottawa Ankle Rules. Patients require ankle X-rays when they present acutely with pain about either malleolus and at least one of the following:

- Bony tenderness about the distal 6 centimeters of either malleous
- Inability to weight bear on the extremity following injury and later on exam

X-rays should include standing anterior-posterior, lateral, and mortise views. Radiographs in an isolated ankle sprain will be normal or may note a small bony avulsion of the distal tip of the lateral malleolus where the ATFL has been torn. A lateral shift of the talus in the ankle mortise or tilting of the talar body suggests an occult ankle fracture (usually proximal fibula) and warrants further imaging.

The Ottawa Foot Rules are also important in the evaluation of patients with ankle injuries and indicate that X-rays are required when patients present acutely with midfoot pain and at least one of the following:

- Tenderness about the base of either the fifth metatarsal or the navicular
- Inability to weight bear on the extremity following injury and later on exam

X-rays should include standing AP, lateral, and oblique views of the foot. Radiographic evaluation of chronic ankle instability should begin with the above-described foot-and-ankle X-rays to rule out pathology that may mimic or contribute to ankle instability. This may include malalignment, arthritis, osteochondral injury, or tarsal coalition. Undiagnosed fractures of the lateral process of the talus are a common source of ankle-instability-like symptoms. A computed tomography (CT) scan is helpful for more detailed imaging where bony pathology is suspected, such as tarsal coalition or bony/articular injury. Magnetic resonance imaging (MRI) is a useful diagnostic adjunct that can reveal swelling, ligament injury, tendon tears, bone bruising, or occult fracture. Synovitis, osteochondral lesions of the talus, loose bodies, and peroneal tendon tears are often seen on MRI in association with chronic ankle instability.

Management

Acute ankle sprains are graded from I to III. Grade I describes a mild ligament stretch with no instability, minimal swelling and tenderness, and no significant functional impairment. Grade II describes partial tears with mild to moderate instability, increased tenderness, and increased swelling. Grade III injuries are characterized as complete rupture of the ligament, significant instability, severe pain and swelling, and significant functional impairment.

Acute ankle sprains are treated with functional management. This consists of *r*est, *i*ce, *c*ompression, and *e*levation (RICE). This is followed by a short period of immobilization (taping, bandaging, or bracing), then physiotherapy (active range of motion, weight bearing, proprioception training, peroneal strengthening). Primary surgical management of acute ankle instability is being debated, but current evidence is lacking to support such management.

Chronic ankle sprains are best managed early in the disease process. Lack of improvement with conservative management warrants referral to an orthopedic surgeon and is an indication for surgery, provided other conditions in the differential diagnosis have been ruled out or addressed. The goal of instability surgery is to restore the deficient soft tissue stabilizers of the ankle. Most procedures address the lateral ankle ligament complex and fall into two major groups: (1) anatomic repair of the ligaments and (2) tenodesis stabilization. Anatomic repair involves re-approximation of the ATFL and possibly CFL to the lateral malleolus or an in-substance repair. Plication of the ligament is often done concurrently to account for lengthening of the ligaments. Modifications of this technique have been described to facilitate repair where the ligament remnants are of poor quality. The most commonly used method of anatomic repair is the Bröstrom procedure.

Tenodesis stabilization procedures are indicated for patients with lateral ankle instability with failed anatomic repair. Some seek to replace the deficient lateral ligaments by rerouting all or a portion of the peroneus brevis to provide the static function of the ATFL or CFL. Other surgeries use hamstring graft to re-create these structures. Overall, outcomes favor anatomic repair over reconstruction due to nerve injury, wound complications, and deteriorating outcomes over time.

With respect to medial ankle instability, most cases can be managed with functional rehabilitation. Surgery to reconstruct the chronically failed deltoid ligament is an ongoing area of interest, but there are no standard reconstructions with predictably good outcomes at present.

Surgical management for instability associated with foot-and-ankle deformity is pathology dependent and may include tendon transfers, osteotomies, or fusions.

Some authors advocate ankle arthroscopy at the time of surgery before proceeding with ligament repair or reconstruction to identify and treat concomitant foot-and-ankle pathology, such as osteochondral lesions of the talus, ankle impingement, or osteophytes.

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See also Ankle Injuries; Ankle Instability, Chronic; Ankle Sprain; Ankle Support; Bracing; Foot and Ankle Injuries, Surgery for; High Arches (Pes Cavus); Musculoskeletal Test, Ankle; Peroneal Tendon Subluxation

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Ankle Instability, Chronic

Chronic instability of the ankle is a condition that may arise after one or more acute ankle sprains. Ankle sprains, which most often involve tearing or stretching of the lateral (outside) ligaments of the ankle during excessive inversion (in which the foot rolls inward), are among the most common injuries in all of orthopedics. Following such acute injuries, the majority of people will have a full functional recovery without surgery. However, around 10% to 20% of people will suffer from chronic lateral instability, in which there is persistent "giving way" of the ankle and recurrent sprains.

Anatomy

Ligaments are strong bands of connective tissue made of collagen fibers. Ligaments surround joints and provide the connection from one bone to another. The lateral ligamentous structures are most commonly affected in both acute ankle sprains and chronic ankle instability. Of the lateral ankle ligaments, the weakest and most frequently injured in inversion injuries is the anterior talofibular ligament (ATFL), which runs from the anterior (front) aspect of the distal fibula distally to the anterolateral aspect of the talus. The ATFL is normally the primary restraint to internal rotation of the foot when the ankle is in plantarflexion (in which the foot is pointing downward relative to the leg).

In more severe ankle sprains, the calcaneofibular ligament (CFL), which runs from the distal tip of the fibula distally (toward the sole of the foot) and slightly posteriorly to the lateral aspect of the calcaneus, may additionally be torn or stretched. Normally, the CFL restrains the internal rotation of the foot during ankle dorsiflexion (in which the foot points upward relative to the leg). Although it is the second weakest lateral ligament of the ankle, injury to the CFL requires more than double the force required to tear the ATFL.

Causes

Severe or recurrent inversion injuries, when forced internal rotation of the foot occurs with the ankle in plantarflexion, are the most common precipitating events that lead to ankle instability. While such injuries frequently occur during athletic activity, accidents during everyday activities or a forceful step on uneven ground may also cause such a sprain.

Chronic instability has been linked to a wide range of etiological factors, which are typically divided into (a) those contributing to mechanical instability, in which the ligaments themselves remain looser than normal after injury, and (b) those contributing to functional instability, in which a person's control or use of the joint is abnormal and predisposes him or her to recurrent injury.

Mechanical instability of the ankle can result from physiologic ligamentous laxity or joint hypermobility, in which a person's ligaments are physiologically looser than normal. Alternatively, a suboptimal healing response in the lateral ankle ligaments may lead to scar tissue that is weaker or elongated following a sprain.

Functional instability stems from loss of proprioception or muscle weakness. Proprioception, the nervous system's ability to detect and control the position of a body part in space, is inherently compromised when the structures around a joint are injured. If there is no adequate retraining of ankle proprioception in the recovery period, this can leave a person prone to recurrent sprains and chronic instability. These proprioceptive qualities also involve the peroneal muscles, which become weaker as a result of the trauma and the immobilization period that typically follows a sprain. Peroneal weakness has been reported in almost one quarter of patients with recurrent ankle sprains.

Symptoms

The primary complaint from patients with chronic ankle instability is a feeling of the ankle giving way or recurrent painful inversion sprain episodes of varying severity. Patients may present acutely with pain, swelling, and ecchymosis about the lateral aspect of the ankle or may present between episodes, when the ankle appears normal but continues to feels "unstable" or "loose."

Diagnosis

The diagnosis of chronic ankle instability is generally made from a history of subjective instability or recurrent ankle sprains for a period of 6 months or longer. Functional instability is evaluated through strength and proprioception testing. Manual strength testing, with specific attention to assessing for peroneal muscle weakness against resisted eversion, should be performed. Proprioception should be evaluated with a modified Romberg test (in which the patient stands on one foot at a time, with the eyes first open, then closed) or with more sophisticated stabilometry testing (available at many physical therapy facilities).

The two primary physical examination maneuvers used for assessment of mechanical instability are the anterior drawer test and the ankle inversion test. The *anterior drawer test* or *prone anterior drawer test* is performed with the patient in the prone (face down) position, with the feet extending over the end of the examining table. The examiner puts one hand on the distal leg for stabilization and pushes the heel steadily forward with the other hand. The test is considered positive when the talus advances anteriorly 3 to 5 millimeters or more. The *inversion stress test,* also called the *talar tilt test,* is designed to assess CFL integrity. The patient lies in the supine (face up) position or on the side, with the foot relaxed and the knee bent, to relax the gastrocnemius (calf) muscle. The talus is then tilted from side to side into adduction and abduction, with a positive test consisting of asymmetry compared with the unaffected side.

Standard radiographs of the ankle (three views—anterior-posterior, lateral, mortise) should be used to rule out fracture following ankle injuries. Rarely, magnetic resonance imaging (MRI) may be used when severe ligamentous injury is suspected and the patient is unable to tolerate physical examination maneuvers because of pain in the acute period.

Treatment

Nonsurgical Treatment

In patients with recurrent instability, if proper compliance with rigorous ankle strength and proprioception training has not occurred, an additional course of physical therapy should be prescribed before surgery is considered, regardless of the chronicity of the symptoms. Around 3 to 4 weeks following a sprain, strength training should be initiated and focused not only on the plantarflexors (calf muscles) and dorsiflexors (anterior shin muscles) of the ankle but also on the peroneal (lateral leg) muscles. Proprioceptive training for the ankle is most commonly performed with a simple tilt board. During athletic competition, ankle taping and use of lace-up braces and "high-top" footwear have been shown to decrease the rate of recurrent sprains.

Surgery

When symptoms of chronic ankle instability last for greater than 6 months and mechanical instability persists despite compliance with a focused functional rehabilitation program, operative treatment should be considered. A number of different procedures have been described to treat chronic ankle instability, which may be divided into (a) anatomic, in which the goal is to repair the normal lateral ligamentous structures, and (b) reconstructive, in which the adjacent tendons are transferred, weaved, or reconstructed so as to provide static stabilization in place of the ligaments. The most commonly used anatomic procedure is the Brostrom-Gould procedure, in which the two ends of the torn ATFL and CFL are each sutured together or imbricated (overlapped) to shorten and strengthen the attenuated ligament-capsule complex. Advancement of the proximal edge of the extensor retinaculum onto the distal fibula reinforces the repair.

Most of the reconstructive procedures, such as the Evans, Watson-Jones, Larsen, and Chrisman-Snook procedures, involve weaving a portion of the peroneus brevis tendon through the fibula to one or more areas on the hindfoot. The more bony sites that are incorporated into the reconstruction, the more stable the ankle is, but with the effect of restricting or altering normal ankle motion to some degree, so use of these techniques should be individualized based on the instability and the goals for functional recovery.

Rehabilitation

While traditional postoperative rehabilitation regimens include long periods of cast or brace immobilization, ranging from 6 weeks to as much as 10 to 12 weeks in nonathletes, more recent evidence suggests that short-term immobilization and initiation of range-of-motion therapy within 2 to 4 weeks may be associated with earlier returns to work and athletic competition. Active eversion/inversion and strength training are delayed until after 6 weeks, to allow for ligamentous healing.

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See also Ankle Injuries; Ankle Instability; Ankle Sprain

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ANKLE SPRAIN

Ankle sprains are one of the most common injuries sustained during recreational and competitive sports such as soccer, basketball, football, and running. Although a common injury, many individuals do not seek medical attention and are self-treated. Depending on the extent of the injury, inadequate treatment of an ankle sprain may lead to chronic pain, decreased range of motion, or instability. In addition, a self-diagnosed ankle sprain may actually be a more severe injury, such as a fracture at or distal to the ankle complex.

Every year, there are 1 to 2 million cases of ankle sprain, constituting 15% to 20% of all sports-related injuries. Of all types of ankle injuries, 75% to 85% are ankle sprains, with the majority of them caused by an ankle inversion injury. Approximately 40% of ankle sprains can lead to chronic injury.

There are a number of contributing factors that may predispose an individual to sustain an ankle sprain, which can include the following:

- Previous history of ankle sprain/injury
- Older individuals who are sedentary

- Overweight individuals/obesity
- "Weekend warriors," who do not train/engage in sports actively and consistently
- Type and frequency of sport that involves more stress on the ankle complex

Anatomy

The ankle is a type of hinge joint. This joint is formed by the articulation of three bones: the talus, tibia, and fibula. The talus acts as a hinge within this complex, allowing the foot to move up (dorsiflexion) and down (plantarflexion). There are two ligamentous complexes that help provide stability to the ankle. The lateral ligamentous complex is made up of three ligaments: (1) anterior talofibular ligament, (2) posterior talofibular ligament, and (3) calcaneofibular ligament. The medial ligamentous complex is also known as the deltoid ligament and is composed of four ligaments: (1) anterior tibiotalar ligament, (2) posterior tibiotalar ligament, (3) tibiocalcaneal ligament, and (4) tibionavicular ligament. Because of these four ligaments, the medial ligamentous complex is more stable than the lateral complex, which is why most ankle sprains are due to an inversion injury. Of all the ligaments, the most common injured ligament is the anterior talofibular ligament (Figure 1).

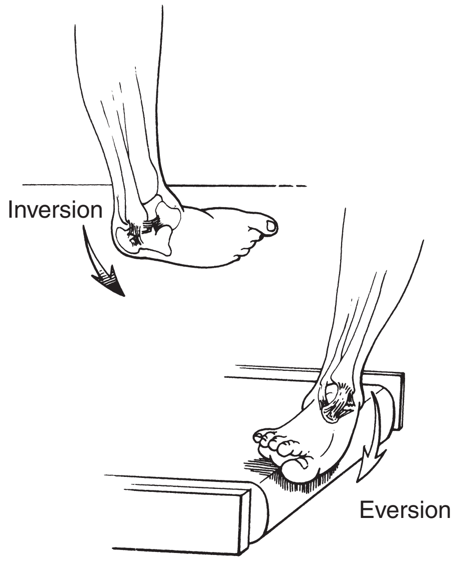

Figure 1 Inversion and Eversion Injuries to Ankle Ligaments

Note: An ankle sprain is a stretch, tear, or complete rupture of one or more of the ligaments that hold the bones of the ankle joint together.

Clinical Evaluation

History

A thorough history will help determine the severity of the ankle sprain as well as aid in determining if it is an injury other than an ankle sprain.

It is important to ask about the position of the ankle at the time of injury, the mechanism of the injury, and the time of the injury. This will help provide the location of the injury site and its associated pathology. A history of past or recurrent ankle sprains provides clues to the overall stability of the ligaments of the ankle and its predisposition to increased frequency of injury. Ascertaining whether the patient was immediately able to bear weight after the injury can provide information as to whether or not a fracture has occurred and the need for radiological evaluation. If the patient is a child, a growth plate fracture is likely, and radiographs of both ankles should be taken for comparison if indicated. A history of numbness in the foot could indicate a neurovascular injury, and proper medical attention should be given.

Physical Examination

When evaluating an ankle injury, the following key features should be addressed.

Inspection. Look for any bruising, discoloration, or swelling both around the ankle joint as well as in structures distal to it (foot and leg). Ask if the athlete can bear weight and also observe his or her gait. Additionally, an inspection of the foot to see if it is pes cavus (arched foot) or pes planus (flat foot) can alter the biomechanics of the ankle joint. Observing the position of the knees, whether they are in valgus (knock-kneed) or varus (bowlegged), can also provide clues to the stress placed on the ankle joint.

Range of Motion. Test the ankle joint both in plantarflexion and in dorsiflexion, as well as inversion (supination). Compare this range of motion with that of the uninjured ankle.

Palpation. Feel the structures around the ankle joint. Pain along the inferior-posterior portion of the lateral ankle joint (distal fibula) may indicate a fracture, whereas pain along the anterior lateral ankle may be a strain of the anterior talofibular ligament. Pain along the inferior-posterior portion of the medial ankle may also indicate a fracture of the distal tibia. It is important to also palpate the surrounding bones of the ankle, including the cuboid, the navicular, and the base of the fifth metatarsal, as these are other commonly missed foot fractures in ankle injuries. Additionally, primary care physicians often miss a fracture of the proximal fibula after a severe ankle injury (Maisoneuve fracture), so every ankle exam should involve palpating the proximal fibula. A connective tissue complex known as the *interosseus membrane* connects longitudinally in between the tibia and the fibula. It is also known as a syndesmosos. This distinct, often missed fracture occurs due to the tremendous force of a high-impact ankle injury, which travels along the syndesmosis and exits at the proximal fibula. Furthermore, palpating distal pulses in the foot and ankle as well as checking for paresthesias may indicate neurovascular compromise.

Additional Testing.

- *Ligament laxity:* Checking for ligament laxity with "drawer tests" can help identify partial or complete tears by physical exam alone. This is performed by stabilizing the area above the ankle joint with one hand and placing the other hand behind the heel (calcaneus) of the foot. With the foot in slight plantarflexion, the examiner applies an anterior force on the heel of the foot to see if the joint will gap. An excessive gap (>4 millimeters) with no end point indicates a complete tear of the anterior talofibular ligament. In addition, checking for gapping and an endpoint during inversion testing will also give clues to a calcaneofibular ligament tear.
- *High ankle sprain:* A "squeeze test" of the distal tibia and fibula resulting in pain can indicate a syndesmotic sprain injury. Additionally, a "crossed-leg" test can also be performed. In this exam, while sitting, the athlete places the lateral side of the ankle on the opposite knee. If there is pain directed to the medial side of the ankle, it can indicate a syndesmotic injury.

Ankle sprains are classified into three grades depending on the severity of the injury:

Grade I: No ligamentous tear, no or minimal loss of function, minimal pain, minimal swelling, no or minimal bruising, and no difficulty bearing weight

Grade II: Partial ligamentous tear, minimal to moderate loss of function, moderate pain, moderate swelling, minimal to mild bruising, some difficulty bearing weight

Grade III: Complete ligamentous tear, severe or complete loss of function, severe pain, severe swelling, mild to severe bruising, and difficulty bearing weight

Imaging Studies

X-Rays

Many believe that all ankle injuries should undergo X-ray evaluation, but this is often debated in medical circles. A cost-effective method to determine if X-rays are needed is to use the Ottawa Ankle Rules, according to which ankle X-ray series should be obtained in case of any one of the following:

- Bone tenderness in the distal 6 centimeters of the posterior-inferior portion of the tibia or fibula
- Inability to bear weight immediately after the injury and in the physician's office/emergency room

Foot X-ray series should be obtained in case of any one of the following:

- Bone tenderness at the base of the fifth metatarsal or navicular bone
- Inability to bear weight immediately after the injury and in the physician's office/emergency room

The use of clinical judgment is emphasized when applying the Ottawa Ankle Rules; their use is at the medical provider's discretion. If a finding on a physical exam is concerning (such as tenderness to palpation at the cuboid), then X-rays should be performed.

If the initial radiographs are negative for fracture but the physician still strongly suspects that there might be one, the patient can be immobilized and given crutches with instructions to return for repeat radiographs in 1 to 2 weeks.

Computed Tomography (CT) Scans

If the radiographs are negative and conservative treatment of a presumed ankle sprain does not improve the athlete's symptoms, a CT scan can be considered to test further for a possible fracture.

Magnetic Resonance Imaging (MRI)

If an athlete has recurring symptoms due to an ankle injury or sprain, an MRI can be considered to further evaluate the soft tissue structures as well as bone contusions or fractures. Depending on the MRI findings, either continued nonsurgical management or surgical intervention may be followed.

Treatment

The basic tenets of ankle sprain treatment include the PRICE (*p*rotection, *r*est, *i*ce, *c*ompression, and *e*levation) method:

For Grade I ankle sprains, protection may or may not be needed. Simple RICE therapy with activity as tolerated is initiated. Initially, range-of-motion exercises are instituted to prevent stiffness, and then gradually, strengthening and balance exercises are recommended.

For Grade II ankle sprains, PRICE treatment is used, and the ankle can be protected with the use of an air-cast splint. Once the pain and swelling have improved, return to activity and stretch/strength therapy are recommended.

For Grade III ankle sprains, the athlete may need to be immobilized in a short leg cast or cast-brace for 2 to 3 weeks. Rarely will an individual require surgery, unless there is another complicated issue. Afterward, treatment is similar to that for Grade I and II injuries.

Anti-inflammatories such as ibuprofen can be used, and analgesics such as acetaminophen may also be helpful for pain control.

Surgical intervention is reserved for those cases where conservative therapy with immobilization and physical therapy has failed.

Prevention of Injury

To help prevent ankle sprains, it is important to review what predisposing factors can be changed.

Those with a previous history of ankle sprains have a higher chance of reinjury, and the greater the number of past sprains the greater the likelihood of recurrence. Lace-up ankle braces have been found to be useful for those with this kind of injury history. Taping can temporarily help stabilize the injured ankle, but it has limited use after 20 to 30 minutes of activity.

Decreasing the amount of stress on the ankle joint will also be helpful. Weight loss in those who are overweight and orthotics for those with foot biomechanic issues can be considered.

Continuous training will help develop strength and proprioception of the ankle, and realizing your body's limits by recognizing the warning signs that you are susceptible to injury is important.

Arnold E. Cuenca

See also Ankle Fracture; Ankle Injuries

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Ankle Support

Ankle support refers to any of several means by which external stabilization can be applied to the ankle joint. This typically includes both bracing devices and taping. Ankle support is relevant to the field of sports medicine because of the high incidence of ankle injuries among athletes participating in sports. Approximately 15% to 25% of all musculoskeletal injuries are ankle sprains. Athletes involved in basketball, football, and volleyball typically have the highest rates of ankle sprains. This entry reviews the types of ankle supports, the indications for their use, and the associated risks and benefits.

Types of Ankle Support

Ankle supports can be categorized as *bracing* or *taping*.

Bracing

Bracing can be divided into rigid and functional. *Rigid bracing* (i.e., a cast or removable boot) is typically reserved for acute injuries and is not adaptable for use during sports since it immobilizes the ankle in all planes of motion. *Functional bracing* allows for improved dorsiflexion and plantarflexion but still limits inversion and eversion motions. Functional bracing is therefore used most often in athletes during recovery from acute injuries and for return to play. The two most common types used for athletes are semirigid and soft braces. Semirigid braces incorporate thermoplastic molded medial and lateral supports that are typically either padded or have air-filled chambers. They are then secured around the lower leg with Velcro straps. Soft braces are canvas or neoprene based, and most lace up the front. Several soft braces have a lateral and/or medial plastic buttress and Velcro straps that secure them into position. They tend to be cheaper than semirigid braces and are easier for the athlete to obtain since they can typically be purchased in pharmacies and sporting good stores. Functional braces range in price from $25 to more than $100.

Taping

Taping is another form of ankle support. Certified athletic trainers (ATCs) are best qualified to tape athletes properly. The exact methods of taping differ, but the basic components of any ankle taping include Tuf Skin application, heel and lace pads with skin lube to prevent skin blisters, alternating anchor strips and horseshoe strips, heel locks, a figure eight, and closing strips to hold it all together. Prewrap is used between the skin and the tape by some athletic trainers. This may reduce skin irritation; however, some athletic trainers feel that it results in less support by the tape. After athletic participation, the tape is removed by cutting it off and is therefore not reusable. The average cost of a roll of tape is around $1.50. Usually, two ankles can be taped with this quantity. Therefore, long-term use of ankle taping can be costly.

An ankle brace makes it possible to compete in sports activities despite an injury.

Source: Can Stock Photo, Inc.

Risks and Benefits of Ankle Supports

Bracing, either semirigid or soft, has several advantages over taping. Although there is an upfront cost to the athlete, it is reusable. Athletes can put on their braces themselves and therefore do not need to have access to an athletic trainer, as for taping. They can also easily adjust the brace's fit for comfort and stability throughout the practice sessions and the competition. Adjustments can be made quickly and without the assistance of a trainer.

The main benefit of taping is that it is less bulky than most braces and therefore can fit easily into all footwear. The cost of taping also usually falls on the athletic department, and therefore, in most instances it is free for the athlete. It also creates a lot of waste since it is disposed of after use. The biggest problem associated with taping is that the tape loosens after approximately 20 minutes. Unfortunately, most athletic practices and competitions outlast the "life" of the tape. Therefore, the protective benefits of the tape are lost, and the athlete may be at an increased risk of injury during this time.

Indications for Ankle Support

Primary Prevention

Very little scientific data exist to support the use of ankle bracing in preventing ankle injuries in an athlete who has never sustained an ankle sprain before. However, primary prevention, or prophylactic use of a brace, is very common. Because basketball, volleyball, and football have the highest injury rates, these are also the sports where the greatest number of athletes choose to use a brace for primary prevention. Functional semirigid or soft braces are the most commonly used.

Acute Injuries

Traditionally, treatment for an acute lateral ankle sprain has been with rigid bracing. In recent years, research has shown that early motion improves recovery, so functional bracing has come into favor. Many athletes who visit an emergency room or require urgent care have their injured ankle placed into a semirigid brace. These athletes will typically need to be transitioned into a soft brace or a semirigid brace with a hinge at the ankle joint to allow more functional athletic movements. Taping can also be applied under the brace to provide a small degree of additional support.

Secondary Prevention/Chronic Injuries

Ankle bracing plays an important role in secondary prevention, the prevention of another ankle sprain after one has already occurred. Scientific evidence overwhelmingly supports the use of an ankle brace during sports after an athlete has sustained an initial ankle sprain. Regular use of a brace can help prevent reinjury as rhe athlete undergoes full rehabilitation with a focus on proprioceptive skills. An ankle brace should be used for 6 months after the initial ankle sprain.

With recurrent ankle inversion injuries, chronic ankle instability may result. Individuals with functional instability can also benefit from the use of ankle braces. Long-term use of bracing may be more beneficial for this athletic population.

Susannah M. Briskin

See also Ankle Instability, Chronic; Ankle Sprain; Bracing; Protective Equipment in Sports

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Anorexia Nervosa

Disordered eating has been found to be more prevalent in athletes than the general population. Various studies have shown the prevalence to range from 15% to 62% among athletes, and female athletes are more often affected than male athletes. Disordered eating includes the spectrum of anorexia nervosa, bulimia nervosa, and eating disorders not otherwise specified. This entry focuses specifically on anorexia nervosa, which is seen in 1% to 3% of the general population, and highlights the importance of proper diagnosis and treatment to prevent its devastating health consequences.

Definition

Anorexia nervosa is defined in the *Diagnostic and Statistical Manual of Mental Disorders*—fourth edition, text revision (*DSM-IV-TR*). It is a type of disordered eating that is characterized by refusal to maintain a normal body weight (less than 85% of expected weight), intense fear of gaining weight (in spite of being underweight), a disturbed self-evaluation of body shape, and three consecutive cycles of amenorrhea.

There are also two specific subtypes of anorexia nervosa: (1) a restricting type and (2) a binge-eating/purging type. In restricting-type anorexia nervosa, the athlete does not regularly engage in self-induced vomiting or the use of laxatives or diuretics. In the binge-eating/purging type, people do engage in these types of behaviors.

Risk Factors

There are many contributing factors that can place an athlete at higher risk for anorexia nervosa. Athletes are most at risk during adolescence and young adulthood. They often face pressure to perform well in their sport from peers, parents, coaches, and others in the community. Athletes are also often placed in an environment where they have a strong personal desire for accomplishment; attaining a certain body type can often help them accomplish their goals.

Participation in certain sports can increase the risk of disordered eating as well. Sports with weight classifications, such as wrestling, boxing, and weight lifting, can lead to disordered eating patterns. In sports such as gymnastics and figure skating, athletes are under greater pressure to maintain a thin body. Also, there are sports where a lean body can contribute to performance, including long-distance running, swimming, and track events.

Additionally, athletes with poor self-esteem, poor body image, a history of sexual abuse, and a family history of substance abuse, mental illness, and disordered eating are at higher risk of developing anorexia nervosa.

Evaluation

Prompt identification of athletes at risk for anorexia nervosa is an important step in prevention of disordered eating. Early intervention can be successful in preventing its devastating health consequences. When there is concern that an athlete is engaged in disordered eating behaviors, a complete history and physical examination are necessary. All athletes should be asked about their training regimen and nutrition history, and female athletes should be asked about menstrual irregularities. Specifically, a nutrition history may include recent weight loss or gain, maintenance of a diet diary, and identifying restrictions on the types of food the athlete eats. They should also be asked about self-image, body satisfaction, performance in classes or work, and satisfaction with current athletic performance. Any coexisting medical disorders should be evaluated, as well as past history of eating disorders and current engagement in any binge-eating/purging type of behavior.

Physical examination should include a head-to-toe evaluation, including a pelvic exam for women. Signs that may be present on physical examination include low body weight, low blood pressure, bradycardia, lanugo (growth of fine, downy body hair), dry skin, thinning scalp hair, decreased body temperature, facial edema, abdominal tenderness, and cardiac arrhythmias. If there is sufficient concern, a complete blood count, a comprehensive metabolic panel, a lipid panel, urinalysis, and a ferritin and thyroid panel should be obtained to rule out specific medical conditions. Common laboratory abnormalities seen with anorexia nervosa include low white blood cell count, elevated liver function tests, increased total cholesterol, hypokalemia, hyponatremia, hypomagnesemia, hypophosphatemia, hypocalcemia, ketonuria, and low ferritin. Additionally, an electrocardiogram (EKG) should be obtained to rule out ventricular arrhythmias. If severe abnormalities are found, urgent inpatient admission may be warranted.

Medical Complications

The adverse health outcomes associated with anorexia nervosa can become chronic, lifelong concerns and may be fatal. There is a 12% to 18% mortality associated with untreated anorexia nervosa. Specific consequences of anorexia nervosa can include menstrual abnormalities, infertility, low bone density, malnutrition, delayed gastric emptying, cardiac arrhythmias, and death. The mental health impacts of disordered eating—poor performance in school, work, and athletics; loss of friendships; and poor self-esteem—are difficult to measure but may be profound.

Treatment

The best treatment for anorexia nervosa is prevention. This should be done by identifying those

Diagnostic Criteria for Anorexia Nervosa

A. Refusal to maintain body weight at or above a minimally normal weight for age and height (e.g., weight loss leading to maintenance of body weight less than 85% of that expected; or failure to make expected weight gain during period of growth, leading to body weight less than 85% of the expected.)

B. Intense fear of gaining weight or becoming fat, even though underweight.

C. Disturbance in the way in which one's body weight or shape is experienced, undue influence of body weight or shape on self-evaluation, or denial of the seriousness of the current low body weight.

D. In postmenarcheal females, amenorrhea, that is, absence of at least three consecutive menstrual cycles (a woman is considered to have amenorrhea if her periods occur only following hormone, e.g., estrogen) administration.

Specify Type:

- Restricting Type: During the current episode of anorexia nervosa, the person has not regularly engaged in binge-eating or purging behavior (i.e., self-induced vomiting or the misuse of laxatives, diuretics, or enemas).
- Binge-Eating/Purging Type: During the current episode of anorexia nervosa, the person has regularly engaged in binge-eating or purging behavior (i.e., self-induced vomiting or the misuse of laxatives, diuretics, or enemas).

Source: American Psychiatric Association. Diagnostic criteria for anorexia nervosa. In: *Diagnostic and Statistical Manual of Mental Disorders*. 4th ed. Text Revision. Washington, DC; 2000.

athletes most at risk for developing disordered eating. This may include athletes with specific family histories, those with a past history of disordered eating behavior, athletes immediately after injury, or athletes in sports that place specific emphasis on thin body types or endurance. Ideally, effective screening for disordered eating should take place at preparticipation physicals each year. Early counseling may be effective in preventing disordered eating.

Treating an athlete with anorexia nervosa requires a well-coordinated team approach. Involvement of the athlete, parents, coaches, athletic trainers, nutritionists, psychologists, and physicians is critical for successful treatment. Any specific abnormalities found on physical exam or laboratory analysis may warrant inpatient hospitalization and should be addressed immediately given the high mortality rate associated with this disorder. Proper outpatient treatment is also critical to avoid any further progression of serious complications. This may include individual or group therapy, and SSRI (selective serotonin reuptake inhibitor) therapy should also be considered. Athletes should be closely monitored for recurrence of disordered eating behavior, as well as for low bone density or menstrual irregularities. Athletes with anorexia nervosa may also need modification of their level of involvement in competition and/or their training program.

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See also Amenorrhea in Athletes; Eating Disorders; Female Athlete Triad

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Anterior Cruciate Ligament Tear

The *anterior cruciate ligament* (ACL) is one of the major ligaments of the knee. It connects the thighbone (femur) and the shinbone (tibia) and prevents the tibia from moving forward when a person turns and pivots. Although a torn ACL used to be an injury that occurred only in athletes, it is becoming more common in any age-group and at various activity levels as more and more people become physically active. Other tissues in the knee, including the meniscus (a fibrocartilaginous shock absorber) may be injured at the same time, as may other ligaments in the knee. The treatment plan will be influenced by what tissues are injured, the current activity level, and what activities the individual would like to do in the future. The final plan of care will be decided on together by the patient and the physician.

Anatomy

The ACL is probably the best known of the four major ligaments of the knee. It connects the tibia, a bone of the lower leg (shinbone), to the femur (or thighbone). It prevents the tibia from moving too far forward in relation to the femur. The ACL has to work the hardest, and is the most important, in sports, where it provides stability during cutting and pivoting motions (e.g., in soccer and football). An injury to the ACL may require surgery followed by a rehabilitation program to allow for return to high levels of activity. The athlete who suspects that he has suffered a knee injury should seek out a qualified physician for an evaluation (Figure 1).

Causes

Most injuries to the ACL occur when an individual makes a sudden cut or turn and the foot stays planted on the ground. Injuries can also take place when landing from a jump (volleyball and basketball) or during contact with another player. Downhill skiing is also an activity that can be a risk for ACL injuries, especially with boots that come relatively high up the calf, which stabilize the ankle but result in increased potential stresses across the knee.

Women are known to be at higher risk for ACL injury than men; however, much of this risk can be reduced by participation in conditioning and training programs that emphasize the importance of strength and flexibility as well as the proper warm-up and cooldown periods. Learning correct jumping and landing techniques is also a critical component of these programs. Programs that take as little as 15 minutes three times a week have been found to be effective. (See the Further Readings. Work on soccer players was spearheaded by Bert Mandelbaum, MD, and Holly Silvers, PT. The website www.aclprevent.com/pepprogram.htm provides a detailed ACL injury prevention program that can be accomplished in 15 minutes three times per week during the season, replacing the traditional warm-up period. Videos and instructions on the Sportsmetrics™ program for collegiate athletes are available through its website, www.sportsmetrics.net.)

Symptoms

Patients who have an ACL injury frequently feel or hear a "pop" in the knee at the time of injury and often will experience swelling within the first 2 hours of injury. This is due to bleeding within the joint from torn blood vessels in the injured ligament. The knee may be painful to walk on, especially if other structures within the knee are also damaged. The instability caused by the loss of the ligament function can result in a "giving way" or "loose" feeling in the knee. This may be particularly noticeable when trying to change directions during walking or running.

After several weeks, the swelling will typically subside, and walking becomes more comfortable. Symptoms of instability that persist often warrant surgical intervention, although some ACL injuries

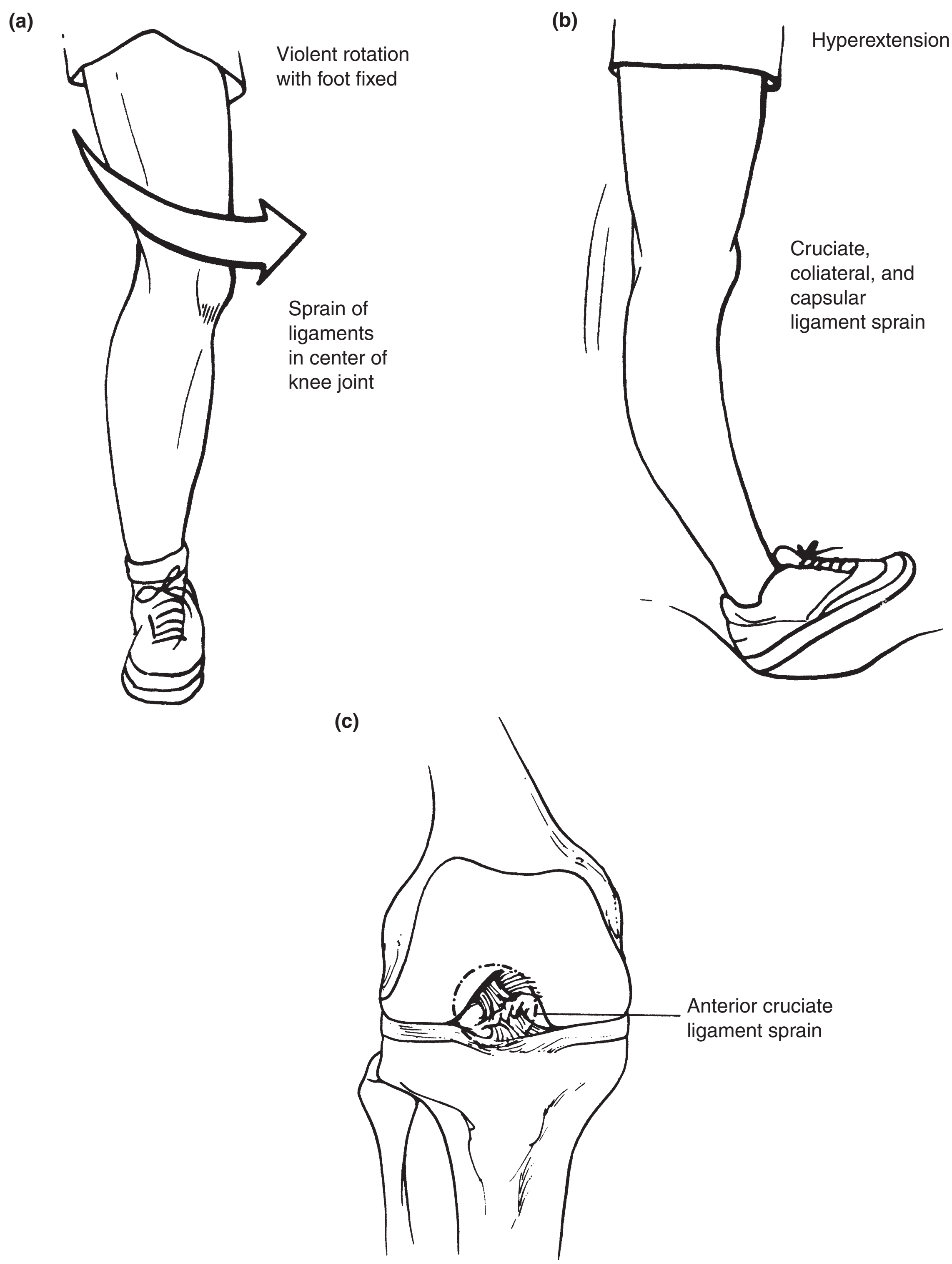

Figure 1 (a), (b) Mechanisms of an (c) Anterior Cruciate Ligament Tear

Notes: An anterior cruciate ligament (ACL) sprain is a stretch, tear, or complete rupture of one of the two ligaments that lie in the center of the joint, connecting the ends of the thigh- and shinbones. Unlike most ligament sprains, which are classified according to severity as first, second, or third degree, ACL sprains are almost always complete ruptures—the ligament is torn completely in two.

can be treated nonoperatively (see discussion below). Long-term instability, or looseness, of the knee, however, is believed to predispose patients to early osteoarthritis.

Diagnosis

The history and physical examination are important for diagnosis of an ACL tear. In an acute (sudden) injury, joint swelling is a good indicator. Swelling that occurs within the first few hours of the injury can be especially indicative of an injury causing bleeding in the joint, while swelling that occurs the next day may be due to the inflammatory response. In addition, examination of the knee with specific tests may be helpful in determining whether the injury is to the ACL or another structure within the knee, such as the menisci or the cartilage.

Imaging of the knee may also be recommended. X-rays can be used to rule out a fracture, but the ACL itself will not be visible on these studies. To assess the ACL, a magnetic resonance imaging (MRI) scan may be ordered. In some cases, arthroscopy (putting a small camera into the joint) may be required to determine if there is a tear in the ACL. This is rarely required; however, if this is needed, treatment of the tear can usually be accomplished at the same time.

Treatment Options: Nonoperative Approach

Some individuals who tear their ACL may elect not to have surgery but may choose to have rehabilitation to treat their knee. People who decide not to have surgery usually do not participate in sports that involve cutting or pivoting activities that would place stress on the knee. Most people with this type of lifestyle will be able to function normally without having surgery to reconstruct their ACL.

Patients are referred to physical therapy to work on walking normally, strengthening, range of motion, and controlling swelling and pain. Even if surgical reconstruction is elected, patients will still need rehabilitation prior to surgery. Most patients are required to achieve normal walking, nearly full motion and strength, and reduced swelling before surgery. This helps minimize problems with motion and strength postoperatively.

Treatment Options: Operative Approach

Surgical Techniques

Because a repair (or suturing together) of torn ACL fibers is not effective, the current surgical treatment of an ACL tear is to remove the torn ACL tissue and replace it with a graft of tendon. Commonly, this is an *autograft* (from the patient's own tissue). There are several choices for where the tendon tissue to replace the ACL can come from. These include two of the hamstring tendons or, less commonly, part of the patellar tendon (the tendon from the patient's kneecap to the bottom leg bone). Allograft tissues that come from a donor can also be used, although these are less frequently recommended as a first-line graft choice in patients under 20 years, owing to the higher failure rate in patients in this age-group. Allograft tissues include either a patellar tendon or other soft tissue, including most commonly the tibialis anterior and Achilles tendons. In a scientific review of autograft choice, the graft does not influence the outcome. Rather, accurate placement by the surgeon, stable initial fixation of the graft, patient compliance, and rehabilitation are believed to optimize the results. The surgeon performs the surgery with the help of a small camera called an arthroscope. The skin incisions are only for the surgeon to harvest the graft if the patient chooses autograft and to drill tunnels at the original site of the ACL. The graft is placed within the tunnels and fixed by any of several means to provide immediate stability prior to healing and to help stabilize the graft to the bone.

Risks of Surgery

Risks of surgery include bleeding, infection (around 1%), nerve or vessel injury (most commonly an area of numbness on the skin adjacent to the incision), failure of the graft (up to 10%), knee stiffness (5–25%), and the need for further procedures. Rare risks include bleeding from acute injury to the popliteal artery (overall incidence is 0.01%), weakness or paralysis of the leg or foot, and a blood clot in the veins of the calf (0.1%). The goal of ACL reconstruction surgery is to prevent instability of the knee. It does not make the knee completely normal or return it to its preinjury status. Patients will still have an increased risk of developing arthritis in the knee after an ACL injury, even if surgery is performed.

Risks Specific to Allograft Use

Allografts are grafts taken from cadavers and are becoming increasingly popular. The advantages of using allograft tissue include elimination of pain caused by obtaining the graft from the patient, decreased surgery time, and smaller incisions. Although there is some theoretical risk of disease transmission, including viral or bacterial infection, the use of allografts that have undergone rigorous donor screening, serological testing, and formal processing has significantly reduced this risk. The Food and Drug Administration (FDA) has regulated this field very closely since 1993 to ensure the safety of allograft transplant. Over the past decade, more than 5 million musculoskeletal allografts have been distributed to surgeons for transplant into patients with a remarkable record of safety.

Alternatives to Surgery

Surgical treatment is usually advised for patients who want to get back to activities that involve cutting and pivoting. However, deciding against surgery is reasonable for select patients. Nonoperative management of isolated ACL tears is likely to be successful or may be indicated in patients

- with partial tears and no instability symptoms;
- with complete tears and no symptoms of knee instability during low-demand sports, who are willing to give up high-demand sports; and
- who do light manual work or live sedentary lifestyles.

In addition, children and adolescents who still have open growth plates should discuss this with their surgeon, along with their parents or guardians. Some patients will be advised to use nonoperative treatment (including bracing, physical therapy, and activity modification) until additional growth is completed, at which time an ACL reconstruction can be performed. For children with open growth plates having instability symptoms even with these treatments, other procedures may be used to temporarily stabilize the knee until growth is near completion, when a standard ACL reconstruction can be performed more safely.

Preoperative Care

The patient who decides to have reconstructive surgery to treat an ACL tear may be asked to have a complete physical exam by the family physician before surgery to assess his health and to rule out any conditions that could interfere with the surgery.

Before surgery, patients should tell their doctor about any medications being taken and will be told which to stop taking before surgery. This typically includes aspirin and anti-inflammatory medications such as ibuprofen (e.g., Advil, Motrin) or naprosyn (e.g., Aleve), all of which should be stopped 10 days before surgery. Acetaminophen (e.g., Tylenol) may be taken in the week preceding surgery, but be sure not to exceed the recommended daily dose.

Tests such as blood samples or a cardiogram may be ordered by the doctor to help the patient prepare for the procedure.

Rehabilitation

Nonsurgical Rehabilitation

Nonsurgical rehabilitation for an ACL injury will typically last 12 weeks if no mechanical symptoms are present (symptoms such as locking, catching, or giving way). This will consist of exercises to strengthen the muscles around the knee, avoidance of high-impact activities, and possibly use of a brace to stabilize the knee during the healing process. The patient can return gradually to activities when there is no more swelling in the knee and no pain and the patient has regained complete strength and control of the knee.

After Surgery

A cast or brace immobilizes the knee after surgery. Patients typically complete a course of rehabilitation exercises before gradually resuming normal activity.

Most doctors will have their patients take part in formal physical therapy after ACL surgery. This is typically a program that emphasizes regaining range of motion and strength of the knee. Many programs consist of a graded set of activities, with the early postoperative exercises putting no stress on the ACL, gradually progressing to more difficult and challenging exercises by the fifth or sixth month.

Martha Murray

See also Knee Bracing; Knee Injuries; Knee Injuries, Surgery for; Knee Ligament Sprain, Medial and Lateral Collateral Ligaments

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Apophysitis

Apophysitis is an overuse injury to a growth plate, commonly seen in young athletes. Apophysitis can be seen in many different parts of the body, including the elbow, pelvis, knee, and foot. It is one of the most common injuries seen in elementary-age children and young adolescents.

Anatomy

An *apophysis* is a bony protuberance near a physis, or growth plate, and serves as the insertion site of major tendons and ligaments. A physis, consisting of cartilage and new bone, is where bones actively grow during development, and as a bone matures, the physis will fuse and become all bone. However, while the physis is still open, it is weaker than all the surrounding tissues, including the formed bone, ligaments, tendons, and muscles, so when stress is applied to an apophysis, it generally is the part that is injured, resulting in apophysitis. In most cases, the tension from a repetitively firing tendon is what causes the apophysitis.

Epidemiology

The increase in organized sports participation has resulted in a similar increase in injuries among pediatric athletes. Increased specialization at a young age, year-round training, and increased intensity of training at an early age also contribute to overuse injuries in general and to apophysitis in particular.

Causes

Most cases of apophysitis have a number of causes. These causes can be divided into two broad categories: intrinsic and extrinsic. Intrinsic factors are issues related to the patient's body. Examples include biomechanical abnormalities such as pes planus (flat foot), pes cavus (high arches), excessive pronation, limb length differences, or abnormal rotation of the thigh (femoral anteversion). Muscular imbalances can be another intrinsic factor. If one muscle is significantly stronger than its antagonist muscle (e.g., the quadriceps and hamstring muscles), then abnormal stresses can occur at a joint, resulting in injury. This often occurs when an athlete focuses too much on one muscle group. Another common cause is inflexibility. Children who are going through their adolescent growth spurt are at risk for this because bones tend to grow faster than muscles, resulting in inflexibility. The growth spurt also happens to be the time when many types of apophysitis are at highest risk. Muscular weakness, poor conditioning, or inadequate muscular endurance can also cause apophysitis.

Extrinsic factors are issues related to the patient's interaction with the environment. Shoes are a common extrinsic factor. It is important for athletes to use shoes that are designed for their sport, appropriate for the competition and practice surface, and correct for their foot type. It is also important to replace shoes regularly; it is generally recommended to replace running shoes every 300 to 500 miles (mi; 1 mi = 1.6 kilometers) and other shoes every season. Training errors are also another common extrinsic factor. Many athletes increase their training intensity too fast, resulting in an overuse injury. Other training errors include improper techniques, such as improper throwing or weight lifting, training on too hard or too soft a surface, or using equipment that is not suited to one's size, age, or ability.

Symptoms and Signs

Most cases of apophysitis have a gradual onset of pain. Pain initially tends to be worse after activity and improves with warming up, but as the pain worsens, it will be present during activity and, eventually, become constant. Specific activities tend to worsen the pain, depending on which type of apophysitis the patient has. There may be swelling, or bony protuberances may become more prominent. Examination will show point tenderness at the site of the apophysitis, and resisted strength testing of the affected tendon may be painful. The natural history of most of these entities is to resolve without sequelae once the physis fuses.

Diagnosis

Most cases of apophysitis can be diagnosed based on the history and physical exam. However, X-rays can sometimes be helpful. X-ray films may show enlargement or fragmentation of the apophysis or widening of the physis. Comparison views of the unaffected limb can be useful to see differences, as the appearance of growth plates can be extremely variable. Magnetic resonance imaging (MRI) and computed tomography (CT) scans are generally not needed unless the diagnosis is in doubt.

Treatment

Treatment will depend on the location of the apophysitis, but there are some general principles. Pain is generally controlled initially by ice and nonsteroidal anti-inflammatory drugs (NSAIDs). Relative rest is often the most important treatment, limiting the activities that cause pain. Rehabilitation to address muscular imbalances, muscular weakness, and lack of endurance is important to allow return to activities. Biomechanical abnormalities should be addressed, often with orthotics or heel lifts. Sports techniques should be analyzed, and if any errors are found, they should be corrected. Return to activities should be gradual, avoiding too rapid an increase in intensity. Since most of the apophysitis will eventually resolve when the physis closes, sometimes treatment involves trying to control the symptoms in order to allow participation until skeletal maturity is reached.

Examples of Apophysitis

Medial Apophysitis of the Elbow

Medial apophysitis of the elbow affects the medial epicondyle, the attachment of the flexor-pronator muscle group and the ulnar collateral ligament. It tends to present in children aged 9 to 14 in overhead sports and is often seen in pitchers who pitch too much or are attempting to break pitches at too early an age. If it is allowed to progress, it can result in an avulsion fracture of the apophysis. It presents with medial elbow pain with throwing, decreased velocity or distance of pitches, and decreased effectiveness while pitching. An exam will show tenderness on the medial epicondyle, a possible flexion contracture, and pain but no laxity with valgus stress testing. Treatment involves rest from all throwing for a minimum of 4 weeks, followed by a progressive throwing program over 6 to 8 weeks.

Iliac Crest Apophysitis

Iliac crest apophysitis is caused by tension on the iliac crest from the oblique muscles of the abdomen and the tensor fascia lata of the lateral thigh. It most commonly presents in runners during the adolescent growth spurt. Pain is worsened by running, walking, and twisting and bending of the torso. Examination will show tenderness over the iliac crest, and often patients will have tight hip flexors and abductors. Treatment involves rest, stretching, and strengthening of the affected muscles.

Osgood-Schlatter and Sinding-Larsen-Johansson Diseases

These two diseases affect the extensor mechanism of the knee. Osgood-Schlatter (OS) affects the tibial tubercle, the insertion of the patellar tendon, while Sinding-Larsen-Johansson (SLJ) affects the distal pole of the patella at the origin of the patellar tendon. They present in preteens (SLJ) or early teens (OS), with anterior knee pain that becomes worse with jumping and running. Patients with OS will often have prominent tibial tubercles. Examination will show tenderness over the distal pole of the patella in SLJ and over the tibial tubercle in OS. Patients will often have hamstring inflexibility. Treatment involves rest, strengthening of the extensor mechanism, and stretching of the hamstrings. Patellar tendon straps may give symptomatic relief.

Sever Disease

Sever disease is apophysitis of the calcaneus and occurs at the insertion of the Achilles tendon into the calcaneus. It presents in 9- to 12-year-old children, especially those who do a lot of running. Pain is worsened by running, kicking, and jumping. Examination will show tenderness over the posterior calcaneus, where the Achilles inserts, and the patient usually has very tight gastrocnemius and soleus muscles. They also often have biomechanical abnormalities with pes planus or excessive pronation. Treatment involves rest, stretching of the calf musculature, and strengthening. A heel lift can provide temporary relief of pain but should only be used for a short period of time as it can actually worsen the flexibility issues.

Michael Stump

See also Medial Apophysitis of the Elbow; Osgood-Schlatter Disease; Sever Disease; Young Athlete

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Arch Pain

The term *arch pain* describes an injury to the plantar fascia ligament of the foot. The *plantar fascia* is a strong fibrous band that runs along the bottom of the foot, starting from the heel bone, spanning the arch, and subsequently inserting into the ball of the foot. Excessive stress on the plantar fascia results in repetitive microtrauma, causing mild tears of the ligament. Arch pain is a common injury in runners and affects both the recreational and the professional runner. However, a nonathlete can also suffer from arch pain as a result of everyday walking or standing activity.

Although arch pain is not dangerous, it can range from mild to debilitating, resulting in limitation of activity. It is frequently seen in middle-aged women and men but can affect all age-groups, especially the very ambitious young athlete. Prompt identification of the causes and early treatment can often limit the course of the injury.

Anatomy

The plantar fascia is a strong band of connective tissue that originates at the heel bone, spans the arch of the foot, and subsequently connects to the toes. The fascia is part of a complex dynamic system of bones, tendons, and muscles of the foot that hold up the arch during weight bearing. The plantar fascia also assists in the transfer of weight from heel to toe during standing, walking, running, and jumping.

Symptoms

Typically, arch pain is described as occurring with the first steps in the morning or when getting up from a seated position. This is because the plantar fascia, foot muscles, and heel cord tighten overnight and while seated, with the foot in a plantarflexed position (toes pointed downward). On standing, the plantar fascia ligament is stretched, and pain results.

The pain symptoms are commonly described as a sharp stabbing or burning sensation. As the patient walks, the ligament loosens, resulting in diminishment of the pain symptoms. The pain will often decrease during activity; however, it typically returns after a period of resting. Frequently, an area of tenderness can be palpated at the medial insertion of the plantar fascia ligament into the heel bone.

Causes

The most common cause of pain of the arch is inflammation of the plantar fascia due to tiny tears of the plantar fascia through chronic repetitive stress. These *microtears* may lead to degenerative changes of the fascia. Excessive stress in a biomechanically imbalanced foot leads to repetitive microtrauma, causing small microruptures of the plantar fascia at its insertion at the heel. This subsequently leads to inflammation and pain. If left untreated, a so-called *heel spur* may develop as a sign of chronic overuse. It is important to note that the spur is only a symptom of the excessive stress and not the cause of the pain.

Certain foot types are predisposed to stress on the plantar fascia. These foot types include flat feet (pes planus) and high-arched feet (pes cavus). Flat feet tend to pronate, resulting in inward rolling of the arch during gait. This motion increases the stress along the plantar fascia ligament. Conversely, high-arched feet tend to have tight calf muscles with shortening of the Achilles tendon and plantar fascia, which also increases the biomechanical stress along the arch.

Injury to the plantar fascia can also result in arch pain. Injuries can be due to excessive training, a sudden increase in training volume, exercising on hard surfaces, and wearing poorly supportive footwear. For the more recreational athlete, body weight seems to be an important risk factor in damaging the fascia over time, consequently leading to pain. It is important to identify the cause of arch pain, whether it is biomechanical imbalance or overtraining. Proper identification will help direct treatment as well as prevent recurrence.

Diagnosis

Diagnosing arch pain is based primarily on patient history of symptoms and clinical examination of the foot. Pain symptoms are usually replicated with palpation of the plantar fascia. The most tender point is usually felt on the medial, plantar aspect of the heel, the major insertion of the plantar fascia ligament into the heel bone.

Imaging studies can be obtained to aid in making the diagnosis as well as ruling out other possible injuries. Plain X-rays of the foot can eliminate bone-related causes of heel pain such as bone tumors and cysts. However, X-rays cannot evaluate the plantar fascia itself. Studies that can examine the plantar fascia include ultrasound and magnetic resonance imaging (MRI). Ultrasound can measure the thickness of the plantar fascia, which is increased following injury. In cases where standard therapy has been ineffective, an MRI study may be appropriate to confirm injury to the plantar fascia and to eliminate causes of pain such as stress fractures of the heel or soft tissue tumors.

Other conditions that may mimic arch pain should be evaluated, especially in patients with ongoing pain and atypical symptoms. These conditions include rheumatoid arthritis, ankylosing spondylitis, Reiter syndrome, rupture of the plantar fascia, stress fracture of the heel bone, calcaneal apophysitis, necrosis of the plantar fat pad, sciatica, and fibromatosis of the plantar fascia.

Conservative Treatment

Treatment should always start conservatively and address the inflammatory as well biomechanical disorders. There is no single treatment that is accepted to be universally successful to treat plantar fasciitis. Instead, the pain symptoms respond to a variety of different conservative therapies.

Conservative care consists of nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroid injections, physical therapy, and home stretching exercises. There is some evidence that the use of NSAIDs may decrease pain and decrease the level of inflammation, but they do not address the biomechanics of the foot.

The biomechanics of the foot can be addressed with taping as well as orthotic devices. Antipronation taping can be done by a physical therapist to prevent the pronation motion that aggravates the arch pain. Over-the-counter orthotic devices can be purchased to prevent pronation and provide support to the plantar fascia ligament. In some cases, custom orthotic devices may be necessary to control the biomechanical factors involved in the arch pain.

Contracture of the plantar fascia and Achilles tendon has been implicated in the development and progression of arch pain. Thus, initiation of physical therapy to stretch these specific contractures is essential for resolution of the arch pain. Additionally, patients are educated on a home stretching regimen to continue treatment and prevent recurrence of the contractures. In addition to stretching, strengthening of specific muscle groups to prevent increased stress on the plantar fascia is effective in the treatment of arch pain.

Stretching of the plantar fascia and Achilles tendon can be achieved with night splints. Worn at night, these braces stretch the contractures while sleeping, reducing the early-morning pain commonly experienced with arch pain.

Physical therapy may also address the inflammation of the plantar fascia ligament with specific techniques such as ultrasound therapy iontophoresis. Iontophoresis uses a small electrical charge to deliver anti-inflammatory medications through the skin to the inflamed area. Use of this therapy can decrease the pain symptoms.

In severe cases that have been resistant to conservative therapy, an injection of corticosteroids in combination with a local anesthetic may be considered. This is typically given when other treatments have failed and pain has persisted for more than 6 months. The injection itself is painful, and there are associated risks, such as a steroid flare reaction, necrosis of the plantar fat pad, and recurrence of pain after a short period of time.

Although discussed controversially in the literature, extracorporeal shock wave therapy has been applied successfully in some cases. Extracorporeal shock wave therapy uses high-energy impulses to inflict microtrauma on the inflamed area. This microtrauma results in new blood vessel formation and promotes healing of the inflamed area.

Finally, modification of training is inevitable. Modification of training should focus on shifting from high-impact activities, such as running, to low-impact activities, such as swimming, treadmill training, or biking. In severe cases, cessation of activity and immobilization may be necessary to allow proper healing of all inflamed tissues.

A combination of conservative treatments has shown a success rate of approximately 90%. Thus, the initial treatment of arch pain should consist of the aforementioned therapies. In case of chronic pain symptoms, surgical intervention should be considered.

Surgery

In some cases, conservative therapy fails to adequately relieve the arch pain. When surgical treatment is required, the procedure of choice typically involves releasing the plantar fascia close to its insertion into the heel bone. If a very large heel spur is present, it may also be resected, but this is not recommended on a general basis. Postoperative healing may take several months, with protection of the heel necessary until the pain decreases. Typical operative complications include poor wound healing, infection, nerve injury, and heel stress fracture from the altered biomechanics of the foot following surgery.

Conclusion

Arch pain can be a significant problem affecting both the professional and the recreational athlete. Early diagnosis and treatment can help limit its course and prevent further interruption of athletic activities. Treatment of arch pain primarily consists of addressing the biomechanical issues and reducing the inflammation of the plantar fascia ligament. In most cases, the treatment of arch pain can be addressed conservatively, with only mild modification of sports activities. However, in severe cases, surgical intervention may be necessary.

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See also Flat Feet (Pes Planus); High Arches (Pes Cavus); Plantar Fasciitis and Heel Spurs

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Archery, Injuries in

Archery is seldom listed as a sport associated with injury. It is, however, far from injury-free. In 1989, D. L. Mann and N. Littke published the findings of a study of injury rates among 21 elite Canadian archers. Shoulder injuries predominated. They pointed out that elite male archers pull a 45-pound (lb; 1 lb = 0.45 kilogram) bow about 75 times a day in competition, approximating 3,400 lb (1,546 kg) pulled in a single day. This represents an enormous strain on the bony, ligamentous, and muscular structures of the shoulder girdle. In 1991, S. Fleck and G. Renfro reported that the rate of shoulder injury among archers approached that of elite swimmers. In 1984, Ann Stirland (senior consultant anthropologist with the Mary Rose Trust) postulated a possible correlation between the shoulder condition os acromiale and the protracted and continual use of heavy-poundage English longbows. The longbow used by the Medieval English archer was a 6-foot (ft; 1 ft = 0.30 meter) yew bow with a draw weight between 80 and 180 lb. Os acromiale is believed to be related to rotator cuff tear and was found in many of the skeletons from Henry VIII's flagship *Mary Rose*.

Based on these reports a web-based pilot study was done in 1996 in Britain on the incidence of injury in archers. The survey was posted on a popular Canadian archery website that was known to be visited by elite archers the world over. It was also published in a number of archery magazines in the United Kingdom and internationally. Archers were asked to report injuries that they believed were connected with their sport. Other data collected included country of residence, gender, the archery discipline, the length of time involved in archery, age at the time of injury, and answers to the following questions:

- Which part of the body was injured and which side?
- Are you right- or left-handed?
- How painful was the injury?
- What treatment was given, and how effective was it?
- How much time was spent away from archery as a result of the injury?
- Do you normally use the services of a physiotherapist?

Although this was a self-reporting study, the results obtained supported Mann and Littke's finding that shoulder injuries predominate in elite archery. In the first 12 months of the survey, over 100 reports were received. These reports represented archers from 20 countries, with the majority of reports received from archers in the United States and Canada. Reports were of persistent pain or loss of function in the upper limb, with shoulder pain predominating, but pain in the elbow, forearm, wrist, and hand was also reported. Less common was back pain and miscellaneous injuries to other areas of the body. Heavier draw weights and frequent archery practice seemed to produce the onset of pain. The majority of injuries involved joints in the upper limb and appeared to be related to the repetitive nature of the action of drawing a bow. These symptoms are related to repetitive strain injury to the rotator cuff in the shoulder and epicondyles of the elbow and if not recognized early can progress to muscular injury at the shoulder and elbow.

Working with the British Archery teams between 1990 and 2006, this author found that the findings of the pilot study were confirmed on a number of occasions, with elite archers suffering rotator cuff damage requiring surgical correction. Archers and their coaches need to be made aware of the risks involved in long hours of archery practice and competition. Early signs of repetitive strain injury often go unrecognized in the effort to achieve competitive success. The archer is often tempted to use too heavy a bow draw weight in striving to shoot longer distances as heavier draw weights produce a flatter trajectory of arrow and tighter groups at longer distances.

In archery, injuries to the shoulder occur due to overuse rather than isolated traumatic incidents. Muscular strains are caused by the extra arrows shot in training, changes in style, shooting an overweight bow, or a rapid return to shooting after layoff. The archer must learn that shoulder pain is a sign of early injury and must take corrective action rather than continue to shoot despite the pain. The best treatment for injury is to prevent it from getting worse when early signs appear. The coach should emphasize the use of a proper shooting technique. Careful matching of bow and arrows to the archer is imperative. The archer should realize the importance of warm-up and training programs to condition the muscles of the shoulder and upper back. Archery is an asymmetrical sport, and there is benefit in cross-training in a symmetrical sport such as swimming so that the balance of shoulder musculature is maintained. There is value in seeking the advice of a sports physiotherapist who understands the sport of archery when planning a training program or when rehabilitating from injury.

Between 1993 and 2001, the subject of sports injury in archery was of prime concern to the FITA (International Archery Federation) medical committee. The committee has since published findings of further surveys on archery sports injury in their book *Sports Medicine and Science in Archery*. The importance of shoulder-strengthening exercises for injury prevention is highlighted. They provide a full training program of exercises for strengthening and conditioning the shoulder.

Wiliam David Hutchinson

See also Overtraining; Sports Injuries, Overuse

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Arousal and Athletic Performance

Understanding how *arousal* (*activation, excitement*) of varying intensity affects athletic performance is important for effective coping with stress-related emotional experiences in sports. What is emotional arousal? How is it manifested and measured? How is it related to the performance process and its outcomes? How can the optimal and dysfunctional effects of emotional arousal on athletic performance be explained? The sections below provide research-based answers to some of these questions.

Arousal as a Category of Bodily Experience

Traditionally, *arousal* describes the intensity of the physiological functions of an organism as a reaction to person–environment (P–E) relationships. However, the definition of arousal as a bodily *reaction* captures only one aspect of P–E relationships. According to Lev Vygotsky, to study something as *indivisible unity,* it is necessary to find a construct that would capture the characteristics of both interacting elements. In psychology, such a construct to study P–E interactions is *experience,* reflecting a person's attitude toward the environment and showing the meaning of environment for the person. Experience has a biosocial orientation because it is always someone's experience of something and as such is best represented as a unit of consciousness. Thus, the analysis of any difficult situation should focus not so much on the situation or on a person per se but on how *this* situation is *experienced* by *this* person.

From this perspective, arousal as *bodily experience* is a component of total human functioning reflecting the nature of past, ongoing, or anticipated P–E interactions. The P–E interactions representing the relationships between task demands and a person's resources include the predominance of an organism over the environment, the balance between a person and the environment, and the predominance of the environment over an organism. Three types of bodily experiences are (1) *statelike* situational experiences; (2) *traitlike,* relatively stable patterns of experience; and (3) *meta-experiences* as preferences and rejections of experiences based on awareness of their helpful or harmful effects. Meta-experiences determine an athlete's appraisal of performance situations and choice of coping strategies.

Multidimensionality of Situational Bodily Experience

Arousal as complex situational bodily experience is multidimensional, and its systems description as a component of performance-related *psychobiosocial states* includes at least five dimensions: *form, content, intensity, time,* and *context.*

Form Dimension

Arousal as situational bodily experience is a component of a performance-induced psychobiosocial state. The form dimension of this state involves several interrelated components with a sample of idiosyncratic descriptive labels (markers): *cognitive* (alert, focused, concentrated, confused, distracted), *affective/emotional* (worried, nervous, happy, angry, joyful, fearful), *motivational* (motivated, willing, desirous, interested), *volitional* (determined, brave, daring, persistent), *bodily (somatic)* (tired, jittery, sweaty, painless, breathless, choking), *motor-behavioral* (sluggish, relaxed, sharp), *operational* (smooth, effortless, easy, clumsy actions), and *communicative* (connected, related, in touch).

Arousal Content

Qualitatively, arousal as a situational *bodily state* of being *awake, activated, excited, energized, wired, psyched up,* or *exhausted* implies different levels of vigor and vitality. These experiences are located in different parts of the body (loose or cold legs, tense face, sweaty arms, and tense neck/shoulders) and accompany unpleasant, stress-related (anxiety, anger) and pleasant (joy, satisfaction, hopefulness) emotions. The physical energy related to these emotions acts to enhance the athlete's performance when properly channelled, whereas detrimental effects are likely when the energy is low or out of control.

The content of bodily experiences can be categorized within the framework of two closely related factors: (1) *hedonic tone* (pleasure/displeasure) and (2) *functionality* (optimal/dysfunctional effects). The four arousal categories derived from hedonic tone and functionality are (1) pleasant and functionally optimal arousal, (2) unpleasant and functionally optimal arousal, (3) pleasant and dysfunctional arousal, and (4) unpleasant and dysfunctional arousal. This framework helps identify the idiosyncratic labels of bodily experiences relevant for performance and reflecting the organism's readiness to perform from an athlete's perspective. Physiological changes (in heart rate, blood pressure, visceral functioning, and other autonomic nervous system reactions) represent another content characteristic of arousal-energizing (or de-energizing) approach and avoidance (or withdrawal) behaviors.

Arousal Intensity

The intensity of the bodily component of performance state characterizes the amount of strength, power, and effort invested in execution of a task and its energizing and organizing effects on performance. Traditionally, the impact of arousal on performance was estimated mainly at the group or interindividual level. This approach ignores the fact that different athletes require different arousal intensity levels (high, moderate, low) to give successful performances. Therefore, it is recommended to focus on estimation of the optimal level of arousal intensity at the individual level.

The "in/out-of-zone" principle (Hanin's individual zones of optimal functioning [IZOF] model) describes emotional arousal/performance relationships at the individual level. Specifically, athletes, depending on their available physical, technical, tactical, and psychological resources and readiness state, perform up to their potential if their actual arousal levels are within earlier established optimal zones of intensity and outside dysfunctional zones of intensity. In contrast, if an athlete's actual state is out of her optimal zone, she is likely to perform below her potential. The in/out-of-zone notion describes an idiosyncratic (high, moderate, or low) range of intensity producing optimal and dysfunctional effects on individual performance.

The concept of "item-intensity specificity," proposed by Charles Spielberger, suggests that the content of items captures the intensity of subjective experiences qualitatively. For instance, anger items vary in their ability to discriminate among different intensities; "upset," "annoyed," and "irritated" qualitatively imply less intensity than items such as "enraged," "furious," or "flared up."

Time and Context Dimensions

The temporal dimension includes the *topological* (phases, cycles, sequencing, periodicity) and *metric* (duration, frequency) characteristics of bodily experiences. Short-term dynamics involve bodily experiences prior to, during, and after a task execution. Current sport psychology research examines mainly precompetition emotions in the preparatory stage of the performance process. The resources-matching hypothesis suggests that optimal and dysfunctional emotions and bodily experiences reflect the availability (or unavailability) of resources and their effective or ineffective recruitment and utilization. Therefore, a change in resources and their recruitment and utilization will result in a change in the athlete's zones of optimal functioning.

The context dimension is an environmental characteristic of the impact of situational, interpersonal, intragroup, and organizational determinants of experience intensity and content in sports. Examples of situational impact are emotional experiences triggered in practice sessions versus competitions. Interpersonal and intragroup emotional responses reflect how an athlete experiences his contacts and interactions with a particular partner (or partners, the team, and management).

Assessment of Arousal

Arousal can be measured using objective and subjective measures. Objective measures are related to the fact that arousal affects several systems in the body. Subjective measures are based on the awareness of athletes and their ability to perceive and report their experiences.

Objective Measures of Arousal

Physiologically, arousal involves activation of the reticular activating system in the brainstem, the autonomic nervous system and the endocrine system, leading to increased heart rate and blood pressure and a condition of sensory alertness, mobility, and readiness to respond. *Physiological* measures of arousal include changes in brain wave patterns (electroencephalography—EEG), skin conductance or resistance (SCR), heart rate patterns (HR) or their variability, blood pressure (BP), and muscle activity (electromyography—EMG). Biochemical measures include epinephrine, norepinephrine, and the steroid hormone cortisol, obtained from urine and blood samples.

Low correlation among physiological measures suggests that different people in the same stressful situation may respond by changes in different measures. For example, one athlete may display an elevated HR or its variability, whereas another athlete may show an increase in BP or EMG. John Lacey's principle of "autonomic response stereotypy" suggests that it is important to identify an individual's predominant experience modality and the profile of the multiple physiological measures.

Subjective Measures of Arousal

Subjective measures of arousal include idiosyncratic bodily experiences that are described by self-generated labels (markers), including perceived heartbeat, a dry mouth, "butterflies in the stomach," cold and clammy hands, trembling muscles, sweating all over, and tension in the face, legs/feet, arms/hands, neck/shoulders, and stomach. The list of bodily markers also includes the characteristics of movements (smooth, easy, tight) and feeling thirst, hunger, cold, or pain (or painlessness).

Three standardized self-report measures to assess global arousal include the Activation-Deactivation Adjective Checklist (AD-ACL), the Somatic Perception Questionnaire (SPQ), and the Bodily Awareness Scale (BAS). (See the Further Readings.) As in the case of physiological measures, it is recommended to develop individualized bodily experience scales for each athlete with self-generated idiosyncratic labels.

Yuri L. Hanin

See also Motivation; Psychology of the Young Athlete; Sport and Exercise Psychology

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Arthritis

Arthritis is defined as pain and inflammation of a joint. Osteoarthritis, rheumatoid arthritis, and gout are the most common. Approximately 40 million Americans have osteoarthritis. This entry discusses the causes, diagnosis, and treatment of these types of arthritis.

Osteoarthritis is believed to be caused by muscle imbalances, acute injury, cumulative injury, and genetic predisposition. *Rheumatoid arthritis* is the result of the immune system attacking the joints. *Gout* is caused by the deposition of uric acid crystals in the joints.

Diagnosis

Risk Factors

Osteoarthritis

Risk factors for osteoarthritis include advanced age, female sex, obesity, activity level, previous injury, and genetics. Osteoarthritis is more common in twins, suggesting a genetic component. Weight loss surgery showed that 89% of people had total resolution of their symptoms with an average weight loss of 98 pounds (lb; 1 lb = 0.45 kilogram). There is an increased risk of lower limb osteoarthritis in previously injured joints and in participants of repetitive, high-impact sports. Increased risk has not been found in recreational exercisers. Regular moderate exercise has been shown to decrease symptoms.

Rheumatoid Arthritis

Rheumatoid arthritis is more common in women and in smokers and their relatives. Seventy-five percent of women will have improvement or resolution of their symptoms during pregnancy. Exercise is not causative. Regular exercisers have been shown to have less fatigue and decreased disability.

Gout

Gout is more likely in those who consume alcohol, eat large quantities of meat or fish, or take water pills for high blood pressure and in men over age 30. There is no known link with exercise.

History

Osteoarthritis

Patients will present with complaints of pain in weight-bearing joints, such as the knees and hips. Onset peaks in the fifth decade but can present at almost any age. Patients describe pain and stiffness that slowly progresses over time to become severe and unremitting. Pain worsens with weight-bearing activities. Osteoarthritis can mimic rheumatoid arthritis, discogenic disease, joint infections, and ligamentous injuries.

Rheumatoid Arthritis

Patients will present with joint pain, swelling, and redness, most commonly in the hands and feet.

These symptoms are often symmetrical and in multiple joints. Pain is usually worse in the morning.

Gout

Gout presents with acute severe pain and swelling in one joint, most commonly the great toe. It can be confused with infection.

Physical Exam

Osteoarthritis

A detailed physical examination should be performed on the affected joints. Joint swelling, tenderness, and decreased range of motion is common. Joints may be slightly warm, but significant redness and warmth may indicate infection or other forms of arthritis.

Rheumatoid Arthritis

Patients will often have pain, swelling, and stiffness in symmetrical multiple joints. The finger and wrists are most commonly involved. Destruction of the finger joints may cause deviation of the fingers away from the thumb. The joints are usually boggy and painful, with decreased range of motion.

Gout

Joints affected by gout will be swollen, red, stiff, and extremely tender with movement. The great toe is most often affected, but gout can occur in almost any joint.

Laboratory Tests

Osteoarthritis

The gold standard for evaluating joint pain is joint fluid evaluation. The joint fluid analysis usually shows mild inflammation in osteoarthritis. There are no specific blood tests for osteoarthritis. Markers for inflammation such as erythrocyte sedimentation rate and C-reactive protein may be elevated, but they are often not necessary for the diagnosis.

Rheumatoid Arthritis

The diagnosis of rheumatoid arthritis can be aided by some blood tests. Rheumatoid factor will be elevated in approximately 70% of people with rheumatoid arthritis, but other rheumatic diseases may also show elevation of this factor. Anticyclic citrullinated peptide antibody (anti-CCP) is a more specific test for rheumatoid arthritis. Joint fluid analysis usually shows moderate inflammation.

Gout

Gout is normally diagnosed through a history and a physical exam. When the diagnosis is unclear, joint fluid can be evaluated for uric acid crystals, which are unique to gout. Checking the blood for uric acid levels is not an accurate test.

Radiologic Studies

Osteoarthritis

Weight-bearing X-rays should be taken of the weight-bearing joints to check for joint space narrowing, bone spurs, and sclerosis. Magnetic resonance imaging (MRI) should be performed if patients have locking or instability to evaluate for other causes of the symptoms.

Rheumatoid Arthritis

X-rays of patients with rheumatoid arthritis will show destruction and erosion of the joint space. Soft tissue swelling will also be seen. Fingers may demonstrate deviation away from the thumb.

Gout

Early gout will show no changes on X-rays. As gout becomes chronic, sclerosis and joint erosions may occur. Chronic gout may also demonstrate tophi, which are whitish nodules from deposition of urate crystals in the soft tissue, commonly just under the skin.

Treatment

Osteoarthritis

Treatment includes weight loss, activity modification, medications, supplements, physical therapy, joint injections, and joint replacement surgery.

Weight loss has been shown to be effective. Diet and exercise are the cornerstones of weight loss.

Activities such as swimming or stationary bicycle are recommended. These activities decrease the stress on the joints compared with activities such as running. Physical therapy can be used to strengthen the joints in order to prepare the patient for increased physical activity.

Acetaminophen is safe and effective when taken at recommended doses. Nonsteroidal anti-inflammatory drugs (NSAIDs) may be added if pain control is not adequate. NSAIDs have been associated with increased risk of bleeding stomach ulcers, heart attack, and stroke.

Glucosamine is an over-the-counter supplement. Some studies indicate that it may be beneficial. A trial is reasonable since side effects are rare. Chondroitin is often found in the same preparation but is not as well studied.

Corticosteroid injections relieve pain by blocking the inflammation. These generally provide short-term relief (1–3 weeks) and sometimes provide long-term relief (6–12 months). There is concern that too many injections may cause damage to the joint.

Hyaluronic acid injections are designed to restore healthy joint fluid but are approved only for the knee. The patient may receive one to five injections depending on the medication chosen. The medical literature confirms that these are more effective than placebo and about as effective as NSAIDs and corticosteroid injections.

Joint replacement surgery is widely available for the knee, hip, and shoulder and in some areas for the thumb, fingers, ankle, and spinal disks. The arthritic cartilage is removed and replaced with special metals and/or plastics. Postoperative rehabilitation may take 6 to 12 months. Major risks include blood clots, infection, nerve injury, and reactions to anesthesia. Patients are recommended to confer with the surgeon to discuss surgical options, risks, and benefits.

Rheumatoid Arthritis

The most effective treatment for rheumatoid arthritis includes early diagnosis and disease-modifying antirheumatic drugs (DMARDs). Patient education regarding the nature of the disease, rest with flares, and appropriate physical and occupational therapy have been shown to improve symptoms. Patients are at increased risk of coronary atherosclerosis and should be monitored for osteoporosis if on corticosteroids and kept up to date with immunizations if on immunosuppressive medications.

Gout

The treatment of an acute gout focuses on pain relief. Prescription-strength NSAIDs are usually recommended first. NSAIDs have been associated with increased risk of bleeding stomach ulcers, heart attack, and stroke. If NSAIDs are ineffective or contraindicated, colchicine may be prescribed. It decreases uric acid levels by eliminating it through the stool. Side effects are diarrhea, cramping, and abdominal pain. Intraarticular corticosteroids may be indicated when oral medications fail.

For frequent and disabling attacks, patients may be started on probenecid. This prescription medication decreases uric acid by increasing its excretion through the kidneys. Eight glasses of water are recommended daily to prevent kidney stones. Probenecid should not be used with aspirin, which blocks its effects. Allopurinol acts to block production of uric acid but has risk for allergic reactions.

Steven James Collina and Adam Chrusch

See also Nonsteroidal Anti-Inflammatory Drugs (NSAIDs); Pain Management in Sports Medicine

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Arthroscopy

Arthroscopy is a technique in sports surgery that is becoming increasingly popular. It involves the insertion of a camera, or *arthroscope*, into a joint through small skin incisions termed *arthroscopic portals*. The image within the joint is then projected onto a video screen and can be used for both diagnostic and treatment purposes. Arthroscopy is a minimally invasive alternative to many open surgeries, with advantages including less pain, smaller incisions, and faster rehabilitation. Arthroscopy can be performed on many joints, but it is most commonly used in the knee, shoulder, elbow, hip, and ankle. The types of surgeries that can be performed arthroscopically and the list of joints in which they can be used is constantly expanding.

Anatomy

A *joint* is an articulation or connection between two bones that allows for movement. The type and structure of the joint will determine the level of movement allowed. For example, the knee is a hinge joint that allows bending (flexion) and straightening (extension) in the leg, whereas the shoulder is a ball-and-socket joint that allows arm motion in any direction. While each joint contains unique components related to its specific function, there are baseline similarities between joints that allow the concepts of arthroscopic surgery to be applied.

Joints are surrounded by a thick tissue called the *capsule*, which forms an enclosed space. The inner layer of the capsule is lined by synovium, which serves as a filter. The synovium secretes joint fluid, which lubricates the joint. There is cartilage attached to the ends of each bone in the joint. The cartilage is a form of connective tissue that resembles the shiny white portion of a chicken bone; it provides a smooth surface for joint movement. There are often ligaments (bundles of fibrous tissue) and tendons (ropelike muscle attachments to bone) that are around and inside joints and serve to stabilize them.

Indications

The indications for arthroscopic surgery include a wide range of conditions that involve the joints and the ligaments inside them. Arthroscopy is primarily performed for diagnostic purposes. In cases where the diagnosis is unclear after physical exam and imaging, some surgeons may opt to perform an arthroscopy to visualize the joint and locate the problem. Generally, the source of the pain can be found and addressed during the arthroscopy.

Debridement is a term used to describe the cleaning of a surface, and it can be applied to the joint. Often, a patient will have an arthroscopy due to pain or limitation of mobility. With arthroscopic debridement, the surgeon can smooth the roughened surfaces that may be causing the pain or excise any tissues that may be causing painful symptoms. Debridement can also be used to wash out a joint infection.

Many types of repairs of ligaments and tendons can be done through arthroscopy. Tears of ligaments or cartilage in the knee, such as anterior cruciate ligament or meniscus tears, can be repaired with the aid of arthroscopy. Shoulder injuries involving torn cartilage or tendons, such as rotator cuff tears and biceps tendon injuries, can also be repaired through arthroscopy. The requirement for arthroscopic repair is that the structure in question be within the joint space and in an area accessible by the arthroscopic tools.

Technique

The setup in the operating room for arthroscopy is very important. (See the entry Operating Room Equipment and Environment.) Like any other surgery, arthroscopy is done under sterile conditions in the operating room. Many surgeons use specific positioning devices to allow the limb or joint to be in the ideal position for the procedure. In some cases, traction with weights attached to the limb may be used to increase the joint space.

Small incisions (0.5 inch [1.3 centimeters]) are made in the skin, and an arthroscopic portal is made to access the joint. Fluid is inserted under pressure into the joint to make the joint space larger. A camera approximately the size of a pencil is inserted through these incisions to visualize the inside of the joint. The image from the camera is projected onto a monitor, which the surgeon will use to direct the movement and position of the camera. Many surgeons use the camera to photograph or videotape their intraoperative findings.

Every arthroscopic procedure begins with a *diagnostic arthroscopy*, which entails looking around the entire joint to either confirm or determine the causes of the patient's symptoms. The joint surface and the ligaments and cartilage in the joint are thoroughly inspected for tears or abnormalities. The recesses, or pockets, of the joint are checked for fragments of bone or cartilage that may indicate previous injury.

During the arthroscopy, the surgeon may use a variety of instruments. A probe, or a small metal hook, is used to feel and move the cartilage and ligaments seen on the camera. A small electric shaving device, also the size of a pencil, may be used to shave off injured or frayed areas of cartilage. Other small tools that fit through the small incisions and act as scissors, graspers, and cutters may be used to remove loose pieces of cartilage that are found in the joint.

In the event that a repair of a tendon or ligament is indicated, the surgeon may use anchors, screws, or sutures to hold the tendon or ligament in place. Many of these fit through the small incisions made for the camera and represent a favorable alternative to open surgery. Often, however, the more complicated cases may require a slightly larger incision in addition to the small incisions, to remove or insert larger tools or materials. Reconstruction, in which tissue is taken from elsewhere and used to re-create a missing or torn structure, is becoming an increasingly popular technique as well.

Benefits

Arthroscopic surgery has many benefits. When compared with open surgery, in which the joint is opened and the procedures are done under direct visualization by the surgeon, arthroscopy offers a minimally invasive approach to these procedures. The arthroscopic procedures require smaller incisions. Therefore, there is less scarring on the skin. There is less disruption of the tissues under the skin and in the joint and, consequently, less pain and faster healing. The smaller incisions also allow a smaller area to be exposed to the air, resulting in decreased risk of infection. Patients also tend to have less pain from the incisions from this procedure and are able to participate in rehabilitation sooner.

Limitations

Not all diseases or conditions involving a joint can be treated with arthroscopy. Some surgeries require large exposures of the joint, which arthroscopy cannot offer. Complicated arthroscopic cases may require the surgeon to repair the joint under direct visualization with an open procedure. This most often happens if a structure that needs to be repaired cannot be reached through the small incision without causing injury to other structures or if there is poor visualization within the joint due to bleeding or other factors. In the event of repeat surgeries, there are often complicating factors such as scar tissue or poor bone quality, which do not allow arthroscopic repair techniques to be used effectively.

After Surgery

Most arthroscopic surgeries are performed as outpatient cases, meaning that you may be able to go home on the day of your surgery. The incisions are small and can often be covered with Band-Aids. Depending on the type and location of the surgery, the surgeon will make recommendations regarding limitation of activity. Some procedures will require strict restrictions on activity and instructions on how to care for the operative site (such as using crutches or restrictions on lifting), while others may have no restrictions. Many people who undergo arthroscopic surgery will need physical therapy before they can resume their normal activities.

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See also Knee Injuries, Surgery for; Operating Room Equipment and Environment; Shoulder Injuries, Surgery for; Sports Injuries, Surgery for

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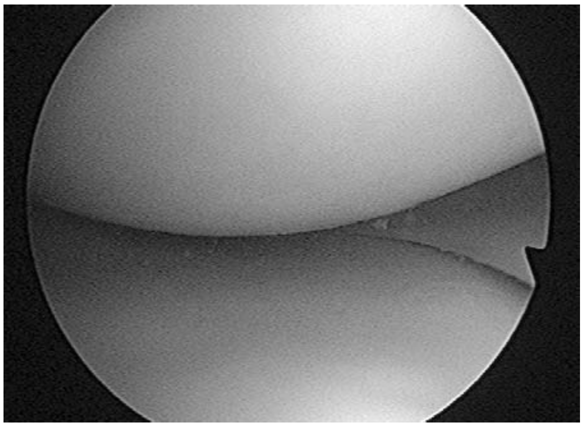
Articular and Meniscal Cartilage Regeneration and Repair

Normal function of the knee in both the athletic and the nonathletic population depends on the integrity of the many components that make up this complex joint. Structures made of cartilage in particular play a key role in maintaining normal function.

Within the knee, there are two different types of cartilage: (1) *articular* (hyaline) *cartilage*, which is the thin layer of smooth, white, shiny tissue covering the articulating bone surfaces, and (2) the *meniscal cartilages*, which are two crescent-shaped wedges of elastic cartilage that lie between these surfaces.

Structure and Function of Articular Cartilage

Articular cartilage has the lowest coefficient of friction of any known substance, which in conjunction with the additional lubrication provided by synovial joint fluid allows the articulating surfaces of the knee joint to slide freely against each other. In the healthy joint, articular cartilage is only a few millimeters thick, increasing in depth where the loads are greatest (see photo at top of column).



Arthroscopic view of femoral articular cartilage

Source: Photo courtesy of Angus Robertson, M.D.

Articular cartilage is made up of cellular and structural components. The cell population is composed of cells called *chondrocytes,* which are predominantly concentrated in the deeper cartilage layers adjacent to the bone surface. The supporting matrix is made up of long molecules called *glycosaminoglycans,* lying within a mesh of Type II collagen fibers. A large percentage of the weight of the tissue is made up of water, which gives the articular cartilage its elasticity and assists in lubrication.

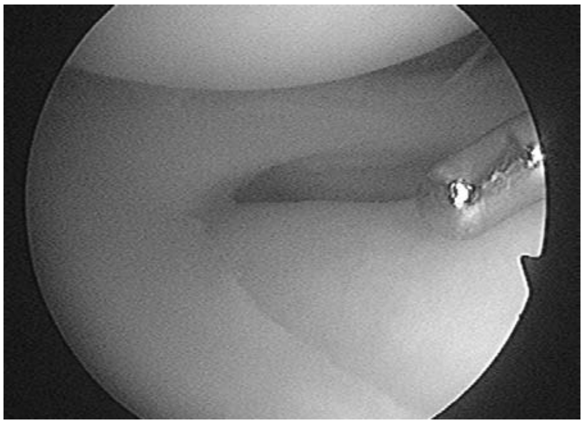
Articular cartilage interfaces with bone at a layer called the *subchondral plate.* Unlike the underlying bone, the cartilage has no blood or nerve supply, which is in part why, when it is damaged, it is particularly poor at repairing itself.

Structure and Function of the Meniscal Cartilages

The meniscal cartilages function as load sharers and shock absorbers. They are crescent shaped when viewed from above and wedge shaped in cross section. There are two meniscal cartilages (menisci) in the knee, one medial and one lateral (see photo on next page). They are made of continuous circumferential bands of Type I collagen fibers attached firmly to bone at each end. Cells called *fibrochondrocytes* are embedded in the tissue. The menisci have a good blood supply around their periphery, extending approximately one third of the way radially into their structure. The remaining inner two thirds of the tissue is avascular. The cells in this part of the menisci are sparse and less metabolically active, taking their nutrition from the diffusion of nutrients and oxygen from the circulating synovial fluid.

Articular Cartilage Injury

Injury to articular cartilage in the knee can vary from small patches of softening or fraying to unstable or loose flaps or even patches of bare bone, where the cartilage has worn away altogether. This can occur through a variety of different mechanisms, including blunt direct or indirect trauma causing anything from minor "bruising" of the cartilage to major damage such as detachment of a fragment of bone and the overlying cartilage—an osteochondral injury. The cartilage may also be damaged by chronic conditions such as osteoarthritis. Disruption of articular cartilage structure and function can result in various symptoms including pain and joint swelling. The joint may click and feel unstable or "give way." Where there is more extensive damage, the knee may become increasingly stiff.



Arthroscopic view of a meniscal cartilage

Source: Photo courtesy of Angus Robertson, M.D.

Meniscal Cartilage Injury

Meniscal injury commonly results from a twisting mechanism on a loaded bent knee. With increasing age, the meniscal cartilages become degenerate, less elastic, and are more liable to tear with minimal or no specific trauma. Classic symptoms include pain along the medial or lateral side of the knee, an effusion, a painful clicking, a sudden painful giving way, and locking (where the joint intermittently gets stuck and the patient is unable to straighten the knee). A variety of different clinical tests have been described for detecting tears. The most popularly used is the McMurray test, which involves putting the knee through a combination of flexion/extension, internal/external rotation, and varus/valgus movements in an attempt to elicit a click/clunk in the knee. The test itself has low sensitivity and only moderate specificity.

Investigations

X-rays have a limited role in investigating cartilage injury in the knee. They may be useful in demonstrating osteochondral injury, in identifying avulsion fractures implying an associated ligament or capsular injury, and in established osteoarthritis. Magnetic resonance imaging (MRI) is now the mainstay of investigation, providing relatively detailed imaging of both articular and meniscal cartilage. However, it is important to emphasize that MRI may still have a false-positive or -negative rate of up to 20% for meniscal tears.

The Treatment of Cartilage Injury

The first-line treatment of a cartilage injury not causing mechanical symptoms includes painkillers, anti-inflammatories, viscosupplementation (intra-articular injection of hyaluronate), and physical therapy. In cases where such measures have failed, a number of surgical options are available.

Most articular cartilage injuries are now treated predominantly using arthroscopic techniques (keyhole surgery). Rough surface cartilage can be smoothed using small motorized shavers or radiofrequency probes that superheat and melt the superficial layers of the cartilage, "welding" together cracks or fissures and "sticking down" unstable edges. When the injury has progressed to expose areas of bare bone, a variety of options are available depending on the size and depth of the defect. For small lesions, it is possible to roughen the bone surface and puncture the area with multiple little holes. This "microfracture" technique produces bleeding into the defect, thereby introducing stem cells from the adjacent bone marrow, allowing a reparative patch of cartilage to form. This cartilage is predominantly fibrocartilage rather than hyaline cartilage and has poorer mechanical properties. In association with the correct rehabilitation protocols, microfracture has reported success rates in the region of 80%. For larger lesions, techniques such as autolgous chondrocyte implantation can be employed. This procedure involves taking samples of cartilage from non-weight-bearing surfaces of the knee, culturing them in a laboratory for about 6 weeks, and injecting the multiplied cells back into the defect under a patch of collagen during a second operation. Alternatives include introducing these cells seeded into collagen membranes or gels, which are then used to fill the defect. Similar success rates to microfracture have been published, with the best results being for defects in the femoral condyles.

Where there is a deeper ostochondral injury, it is not enough simply to replace the cartilage layer. To restore the articular surface, osteochondral plugs must be taken from non-weight-bearing areas of the knee or from tissue donors and inserted into the defects. Synthetic engineered alternatives are also now available.

The meniscal cartilages have poor blood supply, and tears frequently fail to heal on their own, without surgical treatment. Most tears, particularly complex degenerate tears in older patients and those at the inner avascular edge of the meniscus, are irreparable, in which case the torn fragment can be removed using arthroscopic techniques. Loss of meniscal function decreases shock absorbancy and increases peak contact pressures, significantly increasing the risk of future arthritis. With this in mind, every attempt is made to preserve meniscal tissue when trimming a meniscal tear, which is termed a *partial meniscectomy*. Some tears in the outer third of the meniscus (where there is reasonably good blood supply) may heal if supported by sutures. Small, fresh tears in younger patients have the greatest chance of successful repair. Technological advances now allow meniscal repairs to be performed with arthroscopic techniques. If a meniscal tear is trimmed, postoperative rehabilitation can be rapid. If, however, a repair is performed, most surgeons will advise that the knee be protected for up to 6 weeks postoperatively, with limited weight bearing and bracing, and patients will be advised not to return to sports before 3 months postoperation.

In those younger patients where a large proportion of the meniscus has been lost, a number of techniques are being developed to try to restore meniscal function. These include the insertion of bioengineered meniscal scaffolds or meniscal allografts (meniscal transplants) into the knee to provide a framework into which the patient's cells grow and regenerate meniscal tissue. The results of these techniques, in terms of improvement in function, have been encouraging in the short term.

The Future

Improved MRI techniques are enhancing the structural imaging of articular and meniscal cartilage and are allowing mapping of metabolic activity within hyaline cartilage. Tissue engineering is increasingly being used to improve the quality of the regenerate articular cartilage produced by the techniques described above. This includes the production of better scaffolds to encourage cellular regrowth and work to improve the understanding of the cellular mechanisms involved in cartilage repair. New biological (absorbable) glues are being developed for meniscal repair, and the potential use of agents such as growth factors to enhance meniscal healing is being explored. In time, it is likely that a combination of gene therapy and tissue-engineering techniques will see patients being able to regrow organs, including the meniscal cartilages. However, at present the best advice remains to protect one's articular and meniscal cartilages through proper warm-up, safe training, good sporting technique, and regular exercise to keep supporting muscles strong and reflexes fast in an attempt to avoid damage to these important cartilage structures within the knee.

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See also Anterior Cruciate Ligament Tear; Arthritis; Knee Injuries; Meniscus Injuries

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Asthma

Asthma is a disease that is characterized by airway hyperresponsiveness, reversible airway obstruction, and airway inflammation. The hyperresponsiveness is caused by an exaggerated bronchoconstrictor response to stimuli such as histamine. Airway edema can be caused by mucous hypersecretion, resulting in the formation of mucous plugs and swelling. This entry discusses various issues related to asthma, including diagnosis, classification, and treatment and management. (See the entry Asthma, Exercise-Induced.)

This is an important topic for sports medicine because undiagnosed or uncontrolled asthma can result in poor athletic performance and inability to achieve top physical fitness. It is important that athletes with asthma be diagnosed correctly and then treated optimally so that they can maximize their athletic potential.

Diagnosis

Clinical Manifestations

The presentation of asthma can vary, but some of the more common symptoms include wheezing (often recurrent), cough, recurrent chest tightness or shortness of breath, and increased sputum production. Symptoms of asthma are often sporadic and become worse at night. Symptoms typically occur or worsen with exercise, viral infections, exposure to allergens or irritants, weather changes (cold air increases symptoms), gastroesophageal reflux, laughing, and crying. The variations of presentation and triggers make an accurate history one of the most important tools in diagnosing asthma.

The physical exam may or may not demonstrate cough or wheezing. Wheezing typically occurs in the expiratory phase, but it can occur during inspiration as well. Other physical exam findings may be signs of allergic rhinitis (see the entry Allergies) and atopic rashes such as eczema.

Diagnostic Testing

Chest X-rays are helpful because they can exclude other causes of wheezing that mimic asthma, such as bronchitis, pneumonia, congestive heart failure, or foreign body aspiration. A typical chest X-ray finding in asthma is lung hyperinflation with a flattened diaphragm. A pulse oximetry reading can also be helpful.

Pulmonary function tests (PFTs) are the gold standard in helping diagnose and manage asthma. Spirometry can be done in the ambulatory or emergency setting and is an objective measure of lung function. Spirometry measures the expiratory flow rates, comparing baseline values based on the patient's age, race, and height. A decrease in forced expiratory volume in the first second after full inspiration (FEV_1) is characteristic in obstructive lung diseases, including asthma and chronic obstructive pulmonary disease. The hallmark of spirometry in asthma, though, is an increase in FEV_1 of >200 ml and of >12% from baseline after use of a bronchodilator. It is recommended to perform spirometry at the initial assessment in order to establish a baseline, after treatment has been initiated and symptoms have stabilized, during periods of prolonged loss of asthma control and at least every 1 to 2 years if the patient is stable.

If spirometry is normal and asthma is still suspected, a methacholine challenge can be done. This is done by having patients breathe increasing concentrations of methacholine and measuring FEV_1 and subjective symptoms after each dose. Testing stops if the methacholine concentration reaches 8 mg/ml without any significant change in lung function. This has a high specificity, meaning that a negative test essentially excludes asthma. A decrease in FEV_1 of greater than 20% from baseline is a positive test.

Peak flows are more variable and less reliable than in spirometry. They should not be used as the primary method of PFT. They are useful for daily outpatient monitoring, for identifying exacerbations, and for assessing the effects of treatment changes.

Classification

Asthma severity is determined by considering a number of different factors. Asthma categories are used to help direct the patient's treatment. If a patient has elements from more than one category, then the patient's asthma is categorized at the level of the most severe symptom. Asthma is categorized as intermittent or persistent, with persistent asthma divided into categories of mild, moderate, and severe. *Note:* The classifications below are for age 12 and older. There is a different set of criteria for children under 12.

Intermittent

Intermittent asthma is categorized by the following criteria:

1. Daytime symptoms occurring two or fewer days per week
2. Two or fewer nocturnal awakenings per month
3. Use of a short-acting beta agonist (SABA) for symptom control less than twice per week
4. No interference with normal activity
5. Normal FEV_1 between exacerbations
6. FEV_1 >80% of predicted value
7. FEV_1/FVC (forced vital capacity) ratio normal
8. One or no exacerbations per year requiring oral steroids

Mild Persistent

Mild persistent asthma is categorized by the following criteria:

1. Symptoms occurring more than twice per week but not daily
2. Three to four nocturnal awakenings per month
3. Use of a SABA for symptom control more than twice per week but not daily
4. Slight limitation in normal activities
5. FEV_1 >80% of predicted value
6. FEV_1/FVC ratio normal
7. Two or more exacerbations per year requiring oral steroids

Moderate Persistent

Moderate persistent asthma is categorized by the following criteria:

1. Daily symptoms of asthma
2. Nocturnal awakenings more than once per week
3. Daily use of a SABA for symptom relief
4. Some limitation in normal activities
5. FEV_1 between 60% and 80% of predicted value
6. FEV_1/FVC ratio reduced by 5% or less
7. Two or more exacerbations per year requiring oral steroids

Severe Persistent

Severe persistent asthma is categorized by the following criteria:

1. Symptoms of asthma throughout the day
2. Nocturnal awakenings daily
3. Use of a SABA multiple times per day
4. Daily activities severely limited
5. FEV_1 <60% of predicted value
6. FEV_1/FVC ratio reduced by >5%
7. Two or more exacerbations per year requiring oral steroids

Treatment

The goals of therapy are essentially to prevent the symptoms of asthma from occurring. Goals include limiting the patient's use of a SABA to less than twice per week, maintaining normal pulmonary function, and preventing loss of lung function. Treatment is also aimed at preventing recurrent exacerbations, keeping the patient as highly functional as possible, and minimizing the adverse effects of therapy. The approach to pharmacotherapy is based on increasing medications until the asthma is controlled and decreasing medications when possible to minimize side effects.

Inhaled corticosteroids are the most potent and consistently effective long-term control medication for asthma. The broad action of inhaled corticosteroids on the inflammatory process may account for their efficacy as preventative therapy, and their clinical effects are important. They reduce the severity of symptoms, improve asthma control and quality of life, improve spirometry, and help prevent exacerbations. Inhaled corticosteroids also diminish airway hyperreponsiveness and have been shown to reduce the use of systemic steroids, the frequency of emergency room visits and hospitalizations, and the incidence of death due to asthma attacks. Early use of low- or medium-dose inhaled corticosteroids has shown significantly improved asthma outcomes. Also, studies have shown that inhaled corticosteroids improve asthma control more effectively, in both children and adults, than leukotriene receptor antagonists or any other single long-term control medication.

For all patients, quick-relief medications may be needed. These include SABAs, which are used depending on the severity of symptoms. These can be used in up to three treatments at 20-minute intervals as needed. More than that amount should warrant a visit to the doctor or emergency room. For patients who have exacerbation of symptoms that cannot be controlled with a SABA alone, a short course of oral systemic corticosteroids may be needed. The use of a SABA is for symptom relief, not prevention. Also, use of a SABA more than twice per week generally indicates inadequate control and the need to step up treatment.

Current guidelines call for a stepwise approach to asthma control. In each step, care should be taken to evaluate the patient, educate the patient about asthma, try environmental control (such as removal of triggers), and manage other comorbidities. Prior to a step up, check adherence to medication, and try to modify other factors that may be triggering the asthma attacks. Last, if a patient's asthma has been well controlled for over 3 months, consider a step down to the previous level.

Step 1: This is usually for those patients with intermittent asthma, and a SABA is the only medicine needed.

Step 2: Steps 2 to 6 are generally for those patients with persistent asthma. In Step 2, the preferred choice of treatment is addition of a low-dose inhaled corticosteroid. Alternatives include cromolyn, leukotriene receptor antagonists (LTRAs), nedocromil, or theophylline (this medicine is rarely used because of the high number of side effects and interactions with other medications).

Step 3: The preferred treatment is a low-dose inhaled corticosteroid and a long-acting beta agonist (LABA) or a medium-dose inhaled corticosteroid. Alternatives are a low-dose inhaled corticosteroid and an LTRA or theophylline or zileuton. Also, consider consultation with an asthma specialist such as an allergist or pulmonologist at this step.

Step 4: The preferred treatment is a medium-dose inhaled corticosteroid and an LABA. Alternatives include a medium-dose inhaled corticosteroid and an LTRA or theophylline or zileuton. A specialist should be consulted at this step.

Step 5: The preferred treatment is a high-dose inhaled corticosteroid and an LABA; also consider omalizumab for patients who have underlying allergies.

Step 6: The preferred treatment is a high-dose inhaled corticosteroid, LABA, and oral corticosteroids, and again consider omalizumab.

Conclusion

Winter sports tend to increase the risk of an asthma attack because of the cold, dry air, but almost any sport can potentially induce an asthma attack. There have been many athletes at the professional and Olympic levels who have a diagnosis of asthma. With proper treatment and monitoring, they have performed well, and some have even won gold medals. As long as athletes with asthma have their symptoms under control, there are no limitations to participation. If the asthma is not well controlled or if it exhibits symptoms, the athlete should follow up with an allergist or a sports medicine physician experienced in treating asthma.

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See also Allergies; Asthma, Exercise-Induced

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Asthma, Exercise-Induced

Exercise-induced bronchospasm (EIB), also known as *exercise-induced asthma* (EIA), is a condition that obstructs the flow of air to the lungs during physical exertion. This condition can adversely affect the performance and fitness of athletes. EIB is defined as the presence of symptoms while exercising or, more formally, as a decline in FEV_1 (forced expiratory volume in the first second after full inspiration) or PEFR (peak expiratory flow rate) shortly after the onset or cessation of exercise. FEV_1 and PEFR are measured by pulmonary function testing. This entry discusses key issues related to EIB, including triggers, diagnosis and testing, treatment, and prevention.

Pulmonary Function Criteria

A 15% decline in FEV_1 with exercise is the generally accepted value for diagnosis of EIB. For people with a known history of asthma, a 20% decline in FEV_1 with exercise is sometimes used as the criterion. The maximal decrease in FEV_1 usually occurs after about 5 to 8 minutes of vigorous exercise, and pulmonary function tests (PFTs) usually return to baseline 60 minutes after exercise.

Epidemiology

Approximately 12% of the total population experiences symptoms of EIB. EIB can be detected in about 41% of those people with a history of allergic rhinitis, and 70% to 90% of asthmatics have EIB. There is equal distribution between the sexes, and it can occur at any age.

Risk Factors

A history of asthma is the biggest risk factor, followed by a family history of asthma, allergic rhinitis, recent infections (especially bronchitis), and chest symptoms such as cough and congestion.

Mechanism

The current understanding of EIB starts with the idea that hyperventilation during exercise causes drying of the airways and the epithelial cells, increasing intracellular osmolarity. This results in the release of mediators including histamine, leukotrienes, and others. These mediators then cause a transient bronchoconstriction or spasm. At the same time, another mechanism of EIB is taking place: The heat loss during exercise and the rapid rewarming of the airways after exercise cause reactive hyperemia of the microvasculature and edema of the airways, which sets up an osmotic gradient. This osmotic gradient results in the release of inflammatory mediators, causing bronchospasm.

Triggers

EIB can be triggered by cold air, dry air, or pollution or allergens in the air. Mouth breathing is more likely to cause symptoms because unlike nasal breathing, which warms the air, mouth breathing does not and is more likely to cause cooling of the airways and trigger EIB. Intense exercise is also more likely to trigger EIB, so sports such as cross-country skiing, basketball, long-distance running, soccer, and hockey are more likely to trigger EIB symptoms. Chemicals such as chlorine in pools, and insecticides, pesticides, herbicides, and fertilizers used in fields can also trigger symptoms.

Diagnosis and Testing

Clinical Signs and Symptoms

These can vary but typically may include wheezing, shortness of breath, cough, chest tightness, chest pain (usually reported more in children), feeling "out of shape," poor athletic performance, early fatigue, and a dry cough postexercise. Patients can have anywhere from one to a few symptoms. These symptoms are all similar to the symptoms found in asthma (see the entry Asthma), but they occur only while exercising and are of a shorter duration.

Physical Exam

Patients can present with some of the following exam findings: wheezing on lung exam, signs of atopic disease (e.g., eczema) on skin exam, cobblestoning or enlarged tonsils on throat exam, sinus tenderness or pressure, or enlarged and boggy turbinates on nasal exam. Patients often present with no clinical findings.

Testing

If the history points to the likelihood of EIB, a trial of albuterol (or another short-acting beta-2 agonist) is often sufficient. If the patient does not respond to the medication, has negligible reduction of symptoms, or has symptoms more consistent with asthma, then further testing is warranted.

Medication and Testing

During pulmonary function testing, certain medications need to be stopped/avoided so as not to confound the testing and produce false-negative results. For further information, see the entry Asthma.

Pulmonary Function Tests

These can range from hand-held spirometry, which can be done in the physician's office, to more formal testing done in a hospital setting, which can include a methacholine challenge or DLCO (diffusing capacity of the lung for carbon monoxide). The methacholine challenge is used to help diagnose asthma, whereas the DLCO test is used to diagnose pulmonary parenchymal disorders, such as chronic obstructive pulmonary disease. PFTs can be performed in many different ways to evaluate for EIB, but the most effective is to try and mimic the sport or activity that causes the athlete's symptoms.

Free Running

Baseline PFTs are performed prior to exercise. Next, the patient runs either outdoors or indoors until he or she has symptoms, and another set of PFTs are done and compared with the baseline PFTs. One of the advantages of this method is that it is the most likely to induce symptoms, is cheap, and requires minimal cardiovascular (CV) monitoring. Disadvantages include difficulty in controlling the environment, such as temperature and humidity, and that it may not trigger EIB in all patients.

Treadmill and Bicycle Ergometer

This testing is done by having the patient either run on a treadmill or ride a bicycle. Among the advantages are that CV and pulmonary monitoring can be done during the workout and the workload can be standardized. Disadvantages include expenses related to the equipment and that this testing is less likely to induce EIB because factors such as temperature, humidity, pollutants, and allergens are less likely to play a role indoors.

Special Testing

At present, the International Olympic Committee (IOC) requires prior notification for the use of a beta-2 agonist. This notification must be accompanied by objective evidence that justifies the need for the medication. At this time, the gold standard is a eucapnic voluntary hyperventilation (EVH) test. This test consists of hyperventilating dry air containing 5% carbon dioxide at room temperature, and a reduction in FEV_1 of greater than 10% is used to make the diagnosis.

Prevention and Treatment

Pharmacologic

Inhaled Beta-Adrenergic Agonists

This is the primary medicine used in prevention and treatment of EIB. Using this class of medicine (e.g., albuterol) about 15 to 30 minutes prior to exercise can often prevent or reduce the symptoms of EIB. A spacer should always be used with this medicine so that the patient receives the maximum amount of medication. Only the aerosolized form of albuterol has been shown to be effective in EIB and asthma. If the albuterol helps the patient, then no further medication is necessary.

Leukotriene Antagonists

This category of medicine can be added as second-line therapy and occasionally as first-line treatment. It is not as effective in athletes with isolated EIB but can help those with underlying asthma.

Inhaled Corticosteroids

These are not effective in isolated EIB but are the mainstay of treatment for athletes with asthma.

Antihistamines and Intranasal Steroids

These medicines can help athletes with underlying allergic rhinitis, which may trigger EIB and EIA.

Nonpharmacologic

There are various other ways to try to help treat and/or prevent the symptoms caused by EIB. Conditioning may help reduce the severity of the symptoms. Patients can be taught to "run through" their EIB, meaning that the athlete continues to exercise while having symptoms, and some athletes can push through these transitory symptoms and continue their exercise. Short bursts of vigorous exercise (e.g., wind sprints) may suppress EIB symptoms and induce short-term refractoriness. Warming up prior to activity induces bronchodilation and refractoriness to EIB, and cooling down after exercise can decrease postexercise EIB symptoms. Other tips include avoiding exercise in areas with a high pollen count or high pollution. Also, cold weather often exacerbates EIB, so exercising indoors during cold weather or wearing a scarf can help. Last, nasal breathing helps warm the air, so avoid mouth breathing.

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See also Asthma; Pharmacology and Exercise

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Athlete's Foot

Athlete's foot, also called *tinea pedis* or *ringworm*, is a rash caused by a fungal skin infection. The skin areas most commonly affected are the plantar surface (sole) of the foot and the web spaces between the toes. It is estimated that at least 70% of all people will have a fungal foot infection at some point in their life. Athletes may be at slightly greater risk because the factors that predispose infection are warm, moist environments, such as those caused by shoe wear and walking barefoot in infected locker rooms and public showers. Other factors that predispose certain populations to infection are medical conditions such as hyperhidrosis (excessive sweating) and those that affect the immune system. It is seen in males more commonly than in females and is uncommon prior to puberty.

Anatomy

The skin has three layers. The deepest layer is called *subcutaneous tissue* and is composed of adipose (fat), nerves, hair follicles, arteries, veins, and sweat and oil glands. The middle layer is the *dermis*. It has two layers and varies in thickness depending on the location in the body. The deepest layer of the dermis is composed of thick collagen fibers, which have parallel alignment with the skin surface. This layer sits just on top of the subcutaneous tissue. The thin, more superficial (outer) layer of the dermis is also made of collagen fibers, which are randomly arranged. The most superficial layer of the skin is the *epidermis*. The epidermis constantly replenishes keratinocytes (skin cells), which flatten, die, and eventually slough. The overall thickness of the epidermis depends on the location in the body. It is thickest in the palms and soles. The epidermis is composed of five layers (from deep to superficial): (1) stratum basale, (2) stratum spinosum, (3) stratum granulosum, (4) stratum lucidum, and (5) stratum corneum. The stratum basale is named for the basal cells that form the base of the epidermis. They lie on top of the dermis, are shaped like columns, and are constantly dividing to replenish cells lost at the surface. Basal cells divide into keratin-producing cells called keratinocytes. These keratinocytes form microscopic spines that link them together; thus, this layer is called stratum spinosum. As the cells migrate toward the skin surface and become progressively flattened, they form a new layer, called stratum granulosum because the cellular cytoplasm appears granular under microscopy. The cells then die and become the outermost layer, the stratum corneum, which is composed of keratin. The keratin layer of the stratum corneum is the only layer infected by the fungi that cause athlete's foot. The stratum lucidum is a transition layer between the stratum granulosum and stratum corneum. It is only found in the thick skin of the palms of the hands and soles of the feet.

Causes

Athlete's foot is an infection caused by a type of fungi called *dermatophytes*. Able to infect only the top layer of dead keratin, dermatophytes affect the skin, hair shafts, and nails. Dermatophytes can be further classified into three genera: *Trichophyton, Microsporum,* and *Epidermophuton*. *Trichophyton rubrum* is the dermatophyte most commonly associated with athlete's foot, and although other dermatophytes can also cause athlete's foot, they are less common. Fungal spores from *T. rubrum* can live in human scales for up to 12 months and are therefore easily transmitted from person to person in locker rooms and public showers.

Symptoms

Fungal infections are frequently asymptomatic; however, some rashes are *pruritic* (itchy) and, if also infected with bacteria, can become painful. Athlete's foot can be categorized into four main types: interdigital (toe webs), moccasin, vesicular (blisters), and ulcerative.

Interdigital infections may be dry or macerated (soft from being wet). The dry type of infection is typically scaly, erythematous (red), and fissured (cracked). In the macerated type, the skin within the toe web is white, moist, peeling, and also sometimes fissured. The web between the fourth and fifth toes is the most common site of interdigital infection, although any of the web spaces can be involved.

In *moccasin*-type infections, the area involved is limited to the soles and lateral portions of the feet. The leading edge of infection is a well-defined line of erythema (redness). It is dry, with a fine scale and hyperkeratosis (thickening of the epidermis). Moccasin-type infections are commonly bilateral (right and left sides).

In *vesicular* infections, the raised, erythematous leading edge of the rash contains vesicles (small fluid-filled blisters) or bullae (large fluid-filled blisters), which are a sign of acute inflammation. The presence of pus indicates secondary bacterial infection.

Ulcerative-type infections are the spreading of interdigital infection to the dorsum (top) or plantar surface of the foot. They have characteristics similar to those of macerated infections and are usually secondarily infected with bacteria.

Diagnosis

Definitive diagnosis is made by obtaining a skin scraping from the leading edge of inflammation. The skin is collected using a No. 15 scalpel blade to scrape skin scales onto a glass microscope slide. The skin scraping is then evaluated for the presence of hyphae (fungus strands) under microscopy using potassium hydroxide (KOH) wet mount preparation.

Treatment

Athlete's foot can usually be treated with topical antifungal medications such as terbinafine (Lamisil), which can be purchased over the counter. Topical prescriptions such as ketoconazole or clotrimazole may also be used. The length of treatment ranges from 1 to 6 weeks depending on which medication is used. Oral prescription medications such as fluconazole or ketoconazole may be required for severe or resilient infections. If complicated with bacterial infection, antibiotics may also be necessary.

Prevention

Warm, moist environments are ideal conditions for athlete's foot. Tight, nonbreathable, or restrictive footwear causes excessive friction and sweating, which encourage fungal growth. Frequent changing of socks, application of powder to absorb moisture, and wearing sandals in locker rooms and public showers are key for preventing infection. Socks are not effective locker room wear for prevention.

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See also Cholinergic Urticaria; Dermatology in Sports; Fungal Skin Infections and Parasitic Infestations; Skin Disorders, Metabolic; Toenail Fungus; Urticaria and Pruritus

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Athlete's Heart Syndrome

The athlete's heart will adapt to the physiologic stress of strenuous physical conditioning. This "remodeling" of the electrophysiological, morphological, and functional status of the heart is normal in highly trained athletes but may be considered abnormal in other, less cardiovascularly fit individuals. These changes are termed *athlete's heart syndrome*. It is important for team physicians, as well as athletic trainers and coaches, to be aware of these adaptations and to avoid overinterpreting them and atttributing them to pathological states.

What Happens to the Heart With Exercise?

There are two basic types of exercise that place demands on the cardiovascular system: *dynamic* and *static exercise*. Both types challenge the heart to adjust to the variations in heart rate, contractility, myocardial oxygen consumption, and wall tension.

Dynamic demand (i.e., running) involves aerobic activity at lower resistance for long periods of time. Cardiac output is maintained by increases in stroke volume and heart rate. Mean blood pressure shows minimal change due to a decrease in peripheral vascular resistance and increase in systolic blood pressure, diastolic blood pressure remaining relatively constant. The heart also responds to aerobic conditioning by adaptations due to both volume and pressure overload. With increased stroke volume and the resulting increased cardiac output, left ventricular end-diastolic diameter increases, with proportional increases in septal- and free-wall thickness to help normalize wall stress. With this pressure overload, the heart increases both septal- and free-wall thickness to stabilize myocardial wall stress (LaPlace's law).

With static exercises such as weight lifting, which is primarily anaerobic, there are smaller increases in cardiac output, moderate rises in heart rate, and mild increases in stroke volume. Peripheral vascular resistance is increased. Free- and septal-wall thickness increases without increasing left ventricular end-diastolic diameter. As a consequence, the ventricular wall thickens to normal wall stress due to high afterload.

Physical Examination

Physical examination of the athletes shows characteristic changes in adaptation to physical activity. In endurance athletes, the pulse slows and increases in amplitude secondary to higher stroke volume and cardiovascular efficiency. Sinus rhythm is the norm, but sinus arrhythmia or premature beats are not uncommon. Additionally, the left ventricular impulse duration may be prolonged and displaced.

The first and second heart sounds may be highly pitched and sometimes split. Occasionally, this splitting of the second heart sound may last longer than 60 milliseconds and suggests a congenital heart lesion, such as an interatrial septal defect. Because of a greater diastolic filling rate, a third heart sound may be heard. Fourth heart sounds are less common but do occur and may be confused with hypertrophic cardiomyopathy or hypertension in older athletes.

Due to higher stroke volumes and the velocity of blood flow, Grades I to II systolic ejection murmurs may be heard in up to 30% to 50% of dynamic athletes. Last, a venous hum may be heard in the supraclavicular fossa due to the development of a thick muscular neck and the altered flow in the jugular vein. Venous hums are considered benign.

Electrocardiographic Changes

Sinus bradycardia is the most common electrocardiographic finding and is most common in endurance athletes. This is due to increased vagal tone. *Sinus arrhythmia* occurs at rest but disappears with exercise. It is also attributed to a "vagotonic" state. Sinus pause may also occur. First-degree *heart block* is seen in athletes and is felt to be due to changes in autonomic input. Second-degree heart block (Mobitz I or II) may also be due to cardiovascular conditioning. Complete heart block is rare in athletes and should be considered abnormal.

Incomplete right bundle branch blocks demonstrating intraventricular conduction prolongation is seen in athletes. Most commonly, this is attributed to right ventricular overload. Complete right bundle branch block or left bundle branch block is not common in the athletic population.

Ventricular hypertrophy is more commonly seen in endurance athletes than in static athletes. Using voltage criteria for left ventricular hypertrophy shows that this is a common condition in athletes. Voltage criteria add the deflections of SV_1 and RV_5, which is considered high if greater than 35 mm for left ventricular hypertrophy. Right ventricular hypertrophy is present if RV_1 plus SV_5 is greater than 10.5 mm.

ST and T wave changes are also reported in athletes due to alterization in repolarization. ST segment elevation and peaked, inverted, or tall T waves are examples of electrographic changes seen in athletes.

Echocardiographic Changes

Changes in the morphology of the heart include thickening of the myocardial walls and chamber enlargement. Often these correlate with the increase in heart size seen on chest radiographs.

Increase in left ventricular end-diastolic cavity diameter is the most common finding in dynamically trained athletes. The values in athletes, though increased in comparison with the control population, are usually lower than those found in patients with valvular or myocardial disease. The increase in left ventricular size is not believed to be solely due to the reduction in resting heart rate but is thought to correlate with the more highly dynamically trained the athlete is. The degree of dilation is usually within the accepted range of normal adult values. Changes may occur early in training, with some reported as early as the first week of training.

Left ventricular wall thickness in the posterior left ventricle and intraventricular septum are reported to be in conjunction with the change in left ventricular diameter. The degree of thickening is believed to correlate with training intensity. Wall thickness changes are generally modest and within the upper range of normal adult values. Thickening may be found in strength-trained and endurance athletes and decreases with deconditioning. Clinical correlation must be considered regarding the ratio of septal- to free-wall thickness, so as not to confuse athlete's heart syndrome with hypertrophic cardiomyopathy. A ratio greater than 1.3 is considered to be consistent with hypertrophic cardiomyopathy. Using this single value to diagnose hypertrophic cardiomyopathy is not recommended.

Increases in left ventricular mass, left atrial size, and right ventricular size have all been reported with athletic heart syndrome.

Exercise Treadmill Changes

Exercise treadmill testing is primarily used in athletes to evaluate aerobic and anaerobic metabolism. Determination of $\dot{V}O_2max$ (volume of maximal oxygen consumption) and anaerobic threshold has value for endurance-trained athletes and may assist in writing a valid exercise prescription.

The predictive value of exercise treadmill tests in evaluatinge coronary artery disease due to premature atherosclerosis or coronary artery anomalies is low because of the low prevalence of these diseases in the general athletic population. Its use in patients with cardiac disease is of unquestioned value in evaluation of coronary artery disease and myocardial perfusion.

Screening the Competitive Athlete

Knowledge of the changes due to athlete's heart syndrome helps the practitioner in the diagnosis of normal conditioning changes in the competitive athlete. Despite this knowledge, athletes are at risk for sudden cardiac death. In athletes younger than 35 years, hypertrophic cardiomyopathy is the most common killer. In those over age 35, atherosclerotic coronary artery disease is the most prevalent. In addition, heart-related cases of sudden death may be attributed to congenital abnormalities of the coronary arteries, Marfan syndrome with aortic dilation and dissection, idiopathic left ventricular hypertrophy, myocarditis, aortic stenosis, mitral valve prolapse, and prolonged QT syndrome, among others.

A cardiac screening questionnaire evaluating the cardiac history of the athlete is the most cost-effective and universally accepted first-line screening method. Parental involvement in filling out the questionnaire is recommended for acquiring complete information from younger athletes.

Physical examination with a careful cardiac examination should also be performed. Examination of the athlete should be done in a quiet setting free from distractions. Resting blood pressure should be evaluated. Using an appropriate-sized cuff is important, especially for bigger athletes. Palpation of radial and femoral pulses evaluates coarctation of the aorta. Ausculation of the heart should be performed by a knowledgeable physician. The first and second heart sounds, extra sounds in the systole and diastole, and systolic and diastolic murmurs should be evaluated and recorded.

Electrocardiograms, echocardiograms, exercise treadmill tests, and laboratory evaluations are usually not effective screening methods but should be reserved for individuals in whom the screening questionnaire and physical examination are suggestive of potential cardiac pathology.

Conclusion

Team physicians' knowledge of athlete's heart syndrome is important to avoid undue anxiety for the athlete due to misdiagnosis of cardiac pathology based on what are in fact normal physiologic changes in the athletic heart. Bradycardia and heart block due to enhanced vagal tone, ST and T wave changes due to early repolarization, eccentric or concentric cardiac enlargement due to chronic hemodynamic volume or pressure overload, and third and fourth heart sounds may all be normal in the athletic heart. Conversely, they may also indicate cardiac disease states. A detailed, accurate cardiac history and a careful physical examination, along with appropriate use of special tests, are indicated in cardiac evaluation of athletes.

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See also Marfan Syndrome; Preparticipation Cardiovascular Screening; Sudden Cardiac Death

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Athlete's Nodules

Athlete's nodules is a term that refers to a broad category of nonnancerous skin conditions affecting athletes that occur in areas of high friction or repetitive trauma. The nodules represent overgrowth of a skin component called collagen and are often referred to as *collagenomas*. Diagnosis is typically uncomplicated. Treatment includes both medical and surgical options. Athlete's nodules are prevented by using properly fitted and padded athletic equipment at all times.

Anatomy

The skin is the largest organ of the body. It covers an area of approximately 2 square yards (1.67 square meters). The skin ranges in thickness from 0.5 millimeters (mm) on the eyelid to more than 4 mm on the palms of the hands and soles of the feet. Up to 15% of a person's body weight is made up by the skin.

The skin has two main layers: (1) an outer layer called the epidermis and (2) an inner layer called the dermis. The outer epidermal layer forms a protective barrier for the body. Skin cells in the deepest layer of the epidermis constantly divide and are pushed to the surface to replace dead skin cells that have been sloughed off. The inner dermal layer supports the function of the epidermis. Inside the dermis is a vast network of blood vessels, sensory nerves, and supporting protein fibers called collagen and elastin. These supporting fibers help maintain the shape and structure of the overlying skin.

Causes

Athlete's nodules are caused by repetitive friction or trauma against the skin. In most cases, the repetitive friction occurs between a piece of the athlete's sporting equipment and its interface with the skin. Over time, the skin responds to the trauma by increasing the amount of supporting collagen fibers in the dermal layer. The nodules form when there is an overabundance of these collagen fibers present at the site of repetitive friction.

An example of this process is seen with chronic rubbing of the feet from wearing tight-fitting athletic shoes. Used over the course of multiple seasons, tight and poorly fitting shoes can lead to athlete's nodules forming on the top of the foot. The top of the foot is where a tight shoe can exert the most pressure. Other examples of this process have been given unique names in the medical literature due to an association with specific sports: (a) surfer's nodules—lesions on the knees of surfers from friction against the surfboard, (b) knuckle pads—pads of skin over the knuckles of boxers from repetitive punching trauma, (c) cycler's nodules—growths on the buttocks of cyclists from friction against the bike seat, and (d) skate bite—nodules on the feet of ice hockey players from wearing tight ice skates. Despite these specific names, athlete's nodules can occur in any individual engaging in any sport.

Symptoms

Athlete's nodules can affect athletes of any age. The prevalence of these lesions is not well-known. The nodules may present without pain or other symptoms. The athlete may only be concerned about the appearance of the lesions.

Diagnosis

Evaluation of a skin lesion for diagnosing athlete's nodules begins with obtaining a careful clinical history. Special attention is paid to the equipment demands associated with the athlete's sport. If the lesion occurs at a site of repetitive friction with a piece of sporting equipment, it is highly indicative of athlete's nodules. Examination is performed with a visual inspection and palpation of the affected area. Athlete's nodules are well demarcated and skin colored. If the clinical history is suggestive, then the diagnosis is usually uncomplicated.

Depending on the site of the skin lesion, other diagnostic possibilities can exist. Other conditions such as skin callus, hypertrophic scar tissue, ganglion cysts, foreign body skin reaction, bursitis, and gout may mimic the features of athlete's nodules. These conditions may be considered before a diagnosis is made.

To confirm a diagnosis of athlete's nodules, a skin biopsy may be performed. A punch biopsy technique is often used to sample the different skin layers in the lesion. With the use of special cellular staining techniques, the biopsy specimen is examined under the microscope to determine the cellular contents and architecture of the lesion. The microscopic appearance of athlete's nodules will show increased density of collagen fibers in the dermis. In some cases, there is buildup of the outermost layer of the epidermis, which can be seen on the biopsy.

Treatment

Once the diagnosis is made, treatment options include medical and surgical therapies. If there is significant buildup of the outer portion of the epidermis, then several topical medical creams can be used to decrease the thickness. These medications include urea, lactic acid, and salicylic acid preparations. Potent steroid creams can be used and applied to the lesion to decrease the overabundance of collagen in the dermal layer. Alternatively, a steroid such as triamcinolone can be injected into the nodule.

Surgical excision of the lesion is another treatment option. However, with any surgical treatment of athlete's nodules, there is risk of scarring of the affected area, development of a hypertrophic scar, and/or recurrence of the nodule. The athlete should be fully aware of these risks before proceeding with an operation.

If the lesions are not bothersome to the athlete, then it may not be necessary to perform any medical or surgical treatment. In most cases, the nodules should improve with modifying and properly fitting the athlete's equipment.

Prevention

Preventing the occurrence of athlete's nodules requires that the athlete use properly fitted equipment. Properly fitted athletic shoes in particular are critical for the running athlete. If an athlete has been diagnosed with a nodule, it is important that his or her personal equipment be modified or refitted to prevent increased pressure or friction on potential sites. Customized protective pads can be worn over vulnerable anatomic sites for a given sport. As an example, in the case of the surfer, simply wearing a wetsuit can dramatically decrease the friction of the surfboard on the knees and can help prevent nodule formation.

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See also Black Nail; Blisters; Calluses; Corns; Dermatology in Sports; Friction Injuries to the Skin; Skin Disorders Affecting Sports Participation

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Athletic Shoe Selection

For athletes, carefully chosen, well-fitted, comfortable athletic shoes are vital to success, while poorly selected, ill-fitting shoes can lead to performance problems. Athletic shoes serve diverse purposes, which include protection from the environment (from impact shock, abrasion, temperature, moisture), comfort, assisting in the prevention of injury, and, additionally in some sports, functioning to couple limbs and feet to the sporting device (e.g., skis, cycling pedals, snowboard, etc.), all of which contribute to optimal performance.

Athletic shoes are big business. The U.S. athletic shoe marketplace is a $19.4 billion per year business. Running shoes make up the largest number of shoes sold, followed by "low-performance" (fashion), basketball, and cross-training shoes. Marketing has always had a large impact on the selection of athletic equipment, particularly shoes. Because it is often hard to discern fact from fiction in advertising, marketing cannot be relied on to inform us about footgear. One must look farther than noticing which champion is wearing which kind of shoes or viewing the running and style magazines, in which one finds images of shoes hot off the waffle iron, shoes with the latest computer chip inside, shoes with springs, and shoes with air cells and gel. The hype surrounding a type of shoe must not be the major influence in selecting athletic shoes.

Advertising by manufacturers of athletic shoes does not stop at old-fashioned print and television advertising but now extends to the web, blogs, and social networks. The founders of Adidas and Puma, the Dassler brothers, were among the first to seek out famous athletes to wear their shoes. They aggressively competed against each other, convincing athletes to wear their products, often by paying them, despite restrictions on amateur athletes endorsing products. Athletes have been pursued to wear shoes to promote sales as far back as the Olympics of 1936. The holder of several world track records and soon to be a four-time Olympic gold medalist, Jesse Owens was persuaded to wear the shoe manufactured by the Dasslers' combined company, before their split. Abebe Bikila, the barefoot marathoner of 1960, was pursued by Tiger, Adidas, and Puma at the

Tokyo Olympics in 1964. He finally wore Pumas during the Olympic marathon event and set a world record. In 1972, Mark Spitz, Olympic swimmer and winner of six gold medals, walked to the podium carrying a pair of Adidas.

Principles of Athletic Shoe Selection

When selecting an athletic shoe, the athlete should make certain to obtain the proper sport-specific shoe. The motions and forces generated differ from one sport to the next. Weight lifting, tennis, and running each require different motions and place varied stresses on the feet and lower body. For example, tennis shoes require side-to-side, or lateral, stability. Lack of lateral stability could result in an ankle sprain. Running shoes, in most cases, are designed for straight-ahead motion and do not provide this type of stability. Sprinters require a shoe designed for forefoot contact, while the elite marathoner needs a shoe designed for midfoot contact.

Fit Comes First

Obtaining a correct fit is the first step in being prepared for athletic participation. With the majority of athletic shoes being sold in high-volume discount chain outlets, there is usually no knowledgeable and properly trained sales person available to assist with fitting. For this reason, a specialty store is important to success in choosing the proper shoe. Pay attention to both length and width. With the vast number of models available in a multitude of widths and sizes, the athlete is usually able to find the right fit. Shoes are now sized in a great range of lengths and in widths from AA to DDDD. Wearing the socks that will be used for participation in sports helps ensure correct foot measurement. However, each manufacturer uses their own models or lasts, over which the shoe is made, with no standardization for length and width. Consequently, precise fit must be checked inside the shoe. Length is usually measured using a Brannock device and then checked in both heel to toe (one finger's width longer than the longest toe is the correct length) and heel to ball. Width is also measured by the Brannock device and then visually examined for correctness. The foot should not press too hard against the upper at its outer borders, nor should it feel lost and float inside the shoe.

Foot Shape

The easiest method to determine one's foot shape is by doing the wet foot/paper bag test. Wet the bottom of the foot with water, step on a paper bag, and note the shape left behind. A significant curvature of the inner (medial) part of the foot indicates a high arch. A relatively bricklike shape with little curvature indicates a flat foot. A mild curve would indicate a normal or average foot type.

The *last* of a shoe refers to two things. One is the shape of the model used to make the shoe, and the second is the model of the foot itself. Here we are concerned with the shape. The average foot is considered to have a medium or normal arch with mild curvature in the horizontal plane. This foot type usually feels most comfortable in a shoe with a semicurved last. The high-arch, C-shaped foot is best fit in a shoe with a curved last. The flat foot, with its typical bricklike outline, feels best in a straight-lasted shoe.

Foot Type

Severe Overpronation

The foot undergoing severe overpronation usually has a low arch. After the heel or midfoot contacts the ground, the heel everts, resulting in a position that makes for inefficiency. This rotation also causes excessive torque and rotary forces in the Achilles tendon and continuing up the leg. The individual with this foot type does best in a motion control shoe. With somewhat less overpronation, one can wear a stability shoe. The additional supportive features included in the motion control shoe are helpful for those who suffer from severe overpronation. These include the long heel counter, external heel counter, multidensity midsole material, combination- or board-lasted shoes, and midsole support devices. The midsole materials are important in contributing to both cushioning and motion control. The major materials employed are based on ethylene vinyl acetate (EVA) and polyurethane (PU). EVA is foamlike and lightweight, providing cushioning and lowering the overall weight of the shoe. PU is denser and more durable, resisting compressive forces. In combination, they create a duo or multidensity midsole, allowing more resistance to the forces of overpronation on the medial (inner) side of the shoe.

Supinated Foot: Underpronator

Individuals with a C-shaped foot who underpronate can be susceptible to impact shock injuries and lateral overload injuries or ankle sprains. Lateral stability is important in a shoe, and one must avoid having too many pronation-resisting features. Neutral shoes are often good for this type of individual.

Cushioning Versus Support

Cushioning is an overhyped and overrated feature for many types of athletic shoes. Other features, including protection from overpronation, are much more important. Current shoes include many features to limit excessive pronation, including rigid heel counter, double heel counter, external heel counter, multiple-density midsole, and a variety of midfoot-stabilizing materials, which are often made of plastic or carbon graphite. The shoe's last shape will also assist in determining which shoe will fit a particular foot type.

Three-Phase Test of Stability

There are three basic tests to perform on a shoe to gauge its basic stability. Start by first grasping the heel of the shoe in one hand while squeezing the heel counter with the other. The heel counter should resist compression. The next test is perhaps the most important—evaluating for flexion stability. Solidly grip the heel of the shoe, and press the forefoot against a solid surface. The shoe should flex at the ball of the foot, where the toes and the foot meet. That is the natural flexion point of the foot, and the shoe should flex at that point. It should not flex in the middle or there may be inadequate resistance to excessive pronatory forces. The third test is for torsional stability. The heel is grasped in one hand and the forefoot in the other. Then try to twist or torque the shoe, and wring it like a towel. The shoe should resist these twisting forces.

Examine Worn and Old Shoes

Examine the sole of the shoe. Carefully observe where wear has occurred. Although many people are surprised that their shoes wear at the rear outer corner, most rear foot strikers wear at this part of the shoe. This is the point of first contact of the shoe with the ground, as most people walk and run with their feet slightly rotated from the center. Runners, however, also have what is called a *narrow base of gait*. A narrow base of gait means that the feet contact the ground close to the midline of the body. This creates additional varus (tilting in) of the limb. Forefoot wear may point to an individual who is a sprinter, runs fast, contacts the ground with the forefoot first, or all of the above. Uneven forefoot wear may show where one metatarsal is plantarflexed (sits lower) relative to the others or where one metatarsal may be longer than the others. With significant forefoot wear, the risk of stress fractures increases.

Next, place the running shoes on a flat surface and look from the back of the shoe to the toe. If the counter of the shoe is tilted in or bulges over the inner part of the shoe, it indicates excessive pronation. Look for a shoe with more stability, or replace the shoe sooner next time.

If the shoe tilts to the outside, it indicates a possible high-arched foot. In some cases, this can lead to ankle sprains. Possibly there may be an increased transmission of forces to the leg and back. Individuals with this type of foot may have lateral knee pain, low back pain, and outer leg pain and should avoid shoes with too much motion control.

Look at the top of the shoe, and note if the outline of the toes is visible. Check if the large or small toe presses against either side of the shoe. If this is so, if discomfort is present, or if there is a history of "black toe," the athlete should consider shoes that are wider or longer, or both.

The athlete with a flexible, pronated foot should consider a stiffer, board-lasted shoe. Look for a good counter and a sole that is rigid until the point where the toes attach. This offers resistance to torsion and inhibits overpronation. Slip-lasted shoes are frequently good for high-arched feet. Combination-lasted shoes are supposed to offer the best of both worlds: stability in the rearfoot and flexibility in the forefoot.

Soles

The sole of a shoe should not be worn down to the midsole. Often, more wear is seen on the outer corner of the heel than on the medial corner.

Carbon rubber is often used in areas of contact to resist wear and tear. Other sole materials with decreasing resistance to wear include tire rubber, solid rubber, EVA, and blown rubber.

Common Shoe Problems

One of the most common flaws in athletic shoes is an improper flex point. Many shoes bend too proximally rather than at the foot's natural bending point where the toes meet the foot. This creates increased tension in the plantar fascia in addition to interfering with the normal bending of the toes. Accordingly, the athlete must make certain there is adequate room at the toes. Finally, each foot needs to be individually measured and fitted. Humans are not bilaterally symmetrical, and often one foot measures a half-size or more larger than the other.

Injury History

Specific injuries should be taken into consideration when selecting an athletic shoe. Consider the thinking process in the following examples. Those with a history of plantar fasciitis will do best with a shoe demonstrating flexion stability. The athlete with a history of Achilles tendinopathy should wear a shoe with a firm midsole, a firm heel, and an adequate heel lift to take tension off the Achilles tendon. Individuals who have suffered from patellofemoral pain syndrome often benefit from a stability shoe with firm heel counters, in addition to physical therapy, quadriceps and gluteal muscle strengthening, and posterior muscle stretching.

Special-Needs Shoes

Athletic shoes can fill many needs. Snowboard shoes, ski boots, and cycling shoes each have a design specific to the sport. Running shoes may be specialized. Trail shoes are adapted specifically to the needs of the surface and environment of the trail. The enhancements that make these shoes better adapted to trail running include tread alterations for traction on wet surfaces, a protection plate (to prevent sharp-object penetration through soft EVA), additional toe protection, waterproofing, and additional lateral stability. Traction on the sole is obtained by mixing rubber derivatives with silica and carbon to provide longer wearing traction. Geometric lug patterns are seen, which provide lateral and forward-backward stability. The lugs have a "bite" that gives additional stability in soft soil. In 2008, as in all recent Olympics, the manufacturers were vying with each other to come up with something special. With temperatures expected to be extremely hot on the running surface, one manufacturer reintroduced soles with rice husks embedded in them to dissipate the heat. Perhaps rice husk soles would help those running the Badwater race in Death Valley, where ground temperatures of 150 °F are reached and the soles can actually melt.

Summary of Select Athletic Shoe Categories

The following are some select athletic shoe categories:

Running shoes: Offer good straight-ahead features; a variety of motion control devices are incorporated; slight heel lift

Court shoes: Tennis and basketball shoes are designed for side-to-side stability; usually a lower heel is present compared with a running shoe

Cross-training shoes: Possibly good for light weight lifting and exercise machines; an all-around shoe, not designed for any sport specifically; we recommend specific shoes for specific sports

Fitting Tips

Here are some tips for a proper shoe fit:

- Look for a sport specific shoe.
- Go to a specialty store.
- Take injury history into account.
- Measure feet each time shoes are fitted.
- When being fitted, wear the customary socks for the sport.
- Sock thickness affects the sizing and fit of shoes. Bring orthotics to fit shoes.
- Fit shoes later in the day since feet expand slightly by then.
- Leave a finger's width in front of the longest toe.
- Make sure both the heel-to-ball fit and the shoe length are matches for the foot.
- Make certain the shoe feels comfortable. It will not be feeling better in a week if it does not feel good right away.

- Check the shoe for manufacturing defects. It should line up perpendicular to the ground and not wobble.
- Replace athletic shoes regularly. Runners should replace shoes every 350 to 450 miles.
- Focus not on the stated size but on the actual fit.
- Do not wear a new shoe in a race or in a long-distance competitive event.

Stephen Pribut

See also Overpronating Foot; Oversupinating Foot; Plantar Fasciitis and Heel Spurs

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Athletic Trainers

Athletic trainers are health care professionals who collaborate with physicians to optimize activity and participation of patients and clients. Athletic training encompasses the prevention, diagnosis, and intervention of emergency, acute, and chronic medical conditions involving impairment, functional limitations, and disabilities.

Typical patients and clients served by athletic trainers include

- recreational, amateur and professional athletes;
- individuals who have suffered musculoskeletal injuries;
- clients seeking strength, conditioning, fitness, and performance enhancement; and
- patients referred by the physician.

Institutions where athletic training services are provided include

- athletic training facilities;
- schools (K–12, colleges, universities);
- amateur, professional, and Olympic sports venues;
- clinics;
- hospitals;
- physician offices; and
- community, recreational, and fitness facilities.

Athletic trainers also work in environments such as the performing arts (groups/companies); industrial, commercial, governmental, military, and law enforcement work settings; the movie industry (on the sets); rodeos; extreme sports; and auto racing.

Athletic trainers work under the direction of physicians and are clinically and academically qualified to medically treat patients and clients of all ages in any physical setting. The U.S. Department of Labor and the American Medical Association classify athletic trainers as allied health professionals. Their official title is certified athletic trainer (ATC) or athletic trainer (AT). All certified or licensed athletic trainers must have a bachelor's or master's degree from an accredited college or university to practice.

Athletic trainers receive a baccalaureate degree with an academic major in athletic training. The bachelor's degrees are in the premedical sciences, kinesiology, exercise physiology, biology, exercise science, or physical education. A similar graduate degree with a major in athletic training is also awarded for entry into the profession. Academic programs are accredited through an independent process by the Commission of Accreditation of Athletic Training Education (CAATE).

The following educational content standards are required for athletic training degree programs. As part of the Basic and Applied Sciences portion of the degree, students must receive formal instruction in the following specific subject matter areas: human anatomy, physics, human physiology, statistics and research design, chemistry, exercise physiology, biology, kinesiology/biomechanics, and rehabilitation.

The professional content of the degree must include formal instruction in the areas of risk management and injury prevention, pathology of injuries and illness, orthopedic clinical examination and diagnosis, medical conditions and disabilities, acute care of injuries and illnesses, therapeutic modalities, conditioning, rehabilitative exercise and referral, pharmacology, psychosocial intervention and referral, nutritional aspects of injuries and illnesses, and health care administration.

Nearly 70% of certified/licensed athletic trainer credential holders have a master's degree or higher advanced degree. Reflective of the broad base of skills valued by the athletic training profession, these master's degrees may be in athletic training (clinical), education, exercise physiology, counseling, health care administration, or health promotion. This majority of practitioners who hold advanced degrees are comparable with other allied health care professionals.

Athletic trainers are regulated and licensed health care workers. While practice oversight varies by state, athletic trainers practice under state statutes recognizing them as health care professionals similar to physical therapists, physiotherapists, occupational therapists, speech language professionals, and others. Athletic trainers are generally categorized as physical medicine and rehabilitation providers. Athletic training licensure/regulation exists in 46 states, with aggressive efforts under way to pursue licensure in the remaining states and to update outdated licensure practice acts.

The independent Board of Certification Inc. (BOC) nationally certifies athletic trainers. Athletic trainers must pass an examination covering topics within the six practice domains of athletic training: (1) prevention, (2) clinical evaluation and diagnosis, (3) immediate care, treatment, (4) rehabilitation and reconditioning, (5) organization and administration, (6) and professional responsibility. Athletic trainers must hold an entry-level bachelor's or a master's degree to become a certified athletic trainer. To retain certification, credential holders must obtain 75 hours of medically related continuing education credits every 3 years and adhere to Standards of Professional Practice. The BOC is accredited by the National Commission for Certifying Agencies (NCCA).

Other independent organizations that support and serve the athletic training profession are the National Athletic Trainers' Association (NATA) Research and Education Foundation (NATA Foundation) and the NATA Political Action Committee (NATAPAC).

The NATA Foundation is a 501(c)(3) nonprofit corporation separate from the NATA. Its mission is "supporting and advancing the athletic training profession through research and education." The NATA Foundation relies on voluntary support to sustain numerous programs to advance the profession. The goals and strategies of the foundation are to (a) advance the knowledge base of the athletic training profession; (b) encourage research among athletic trainers, who can contribute to the athletic training knowledge base; (c) provide forums for the exchange of ideas pertaining to the athletic training knowledge base; (d) facilitate the presentation of programs and the production of materials providing learning opportunities about athletic training topics; (e) provide scholarships for undergraduate and graduate students of athletic training; and (f) plan and implement an ongoing total development program that establishes endowment funds, as well as restricted and unrestricted funds, that will support the research and education goals of the foundation. To date, the NATA Foundation has awarded over $2,284,387 in research grant funding.

The NATAPAC works on behalf of all certified athletic trainers and the people they treat. Its goal is to enhance health care, both for those who provide it and for those who receive care. NATAPAC is the voice of the athletic training profession. This political action committee seeks on behalf of athletic trainers the right to practice to the fullest extent of their scope of practice, as defined by state licensure or regulation, and fair access to the health care market as physical medicine and rehabilitation providers. Like all political action committees, NATAPAC works to effect change by supporting federal candidates for public office whose views and intentions align with NATAPAC goals.

Athletic trainers are also part of the American Medical Association's Health Professions Career and Education Directory. Athletic trainers are assigned National Provider Identifier (NPI) numbers, as all other health care professionals. Additionally, the American Academy of Family Physicians, American Academy of Pediatrics, and American Orthopaedic Society for Sports Medicine, among many others, are all strong clinical and academic supporters of athletic trainers.

The American Medical Association provided Current Procedural Terminology (CPT) codes

(97005, 97006) for athletic training evaluation and reevaluation. Additionally, the American Hospital Association has established Uniform Billing (UB) codes, or revenue codes, for athletic training.

The NATA, founded in 1950, represents more than 33,000 members of this international profession. Of the total membership, 26,000 are certified/licensed athletic trainers, representing about 85% of all athletic trainers practicing in the United States. The remaining 7,000 NATA members are noncertified professionals and nonlicensed students. The NATA accurately claims the distinction of representing the greatest majority of athletic training professionals worldwide.

The NATA is dedicated to enhancing the quality of health care provided by athletic trainers and to advancing the athletic training profession. The NATA represents and supports the members of the athletic training profession through public awareness, legislative and regulatory advocacy, education, and research. Its slogan is "NATA: Health Care for Life and Sport."

Brian M. FitzGerald

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U.S. Bureau of Labor Statistics: http://www.bls.gov/oco/ocos294.htm

Atlantoaxial Instability

Atlantoaxial instability (AAI) is the loss of stability at the junction between the first cervical vertebra (C1, atlas) and the second cervical vertebra (C2, axis). This is usually due to a problem with the ligament that helps stabilize the two bones, but it may also arise from bony defects. The main concern is that excessive movement at the C1-C2 joint may damage the spinal cord.

The diagnosis cannot be made clinically but must be made by radiographs. Once the diagnosis is made, however, the clinical symptoms and signs are more important. Many people with AAI are asymptomatic. However, patients who are symptomatic need prompt and aggressive evaluation and intervention to decrease the risk of permanent neurologic damage.

Anatomy

The odontoid, or *dens*, is a bony prominence arising from C2 that joins C1 near the back of the spinal column. It is held in place by the transverse ligament. This joint rotates when we turn our heads.

AAI is defined by measurements on X-rays. The atlanto-dens interval (ADI) is the primary measurement. AAI is diagnosed in adults with an ADI greater than 2.5 millimeters (mm) and in children with an ADI greater than 4.5 mm.

Many athletes are asymptomatic, and there is no good evidence that people with asymptomatic AAI are more likely to develop symptomatic AAI. Also, the condition may develop and progress over time, so it is worth following patients to inquire about new symptoms.

Causes

Athletes with Down syndrome (Trisomy 21) are potentially at high risk for this injury. The transverse ligament is usually loose, so it cannot hold the dens against C1. However, these patients may also have inadequate bone formation of the dens, C1, and C2. Approximately 20% of patients with Down syndrome have AAI, while only 2% are symptomatic.

Patients with rheumatoid arthritis (RA) have a higher risk for AAI (up to 60%) and symptomatic AAI. Traumatic injury can cause cervical fractures, leading to AAI. Patients with osteogenesis imperfecta, neurofibromatosis, and several rare syndromes have a higher risk for AAI.

Clinical Evaluation

In sports medicine, most cases of AAI will involve clearance of Special Olympics athletes. It may be difficult to get an excellent history and physician exam due to their cognitive delays. The Special Olympics requires all athletes with Down syndrome to have a screening evaluation and radiographs to evaluate for AAI. It is very important to distinguish between symptomatic and asymptomatic AAI by clinical correlation of radiographs with history and physical exam.

History

The symptoms associated with AAI are neck pain, easy fatigability, difficulty walking, abnormal gait, increased clumsiness, and numbness and tingling in the arms. Patients may complain of neck stiffness and decreased neck motion. These symptoms may have been present for some time and can continue to progress.

Physical Exam

Abnormal findings include decreased range of motion in the neck, increased reflexes all over the body, and spasticity of the muscles. A complete neurologic exam should be performed.

Diagnostic Imaging

X-rays should be obtained with the neck in neutral, flexion (45°), and extension positions. The ADI is maximal in flexion and should decrease in extension. There are other methods to measure for AAI, but they are not commonly used by all physicians and not accepted by the Special Olympics.

For patients with symptomatic AAI, magnetic resonance imaging (MRI) should be performed. This allows for detailed evaluation of the spinal cord and spinal canal. It also can be used to measure the space available for cord (SAC), which may be a more accurate predictor of neurologic injury (Figure 1).

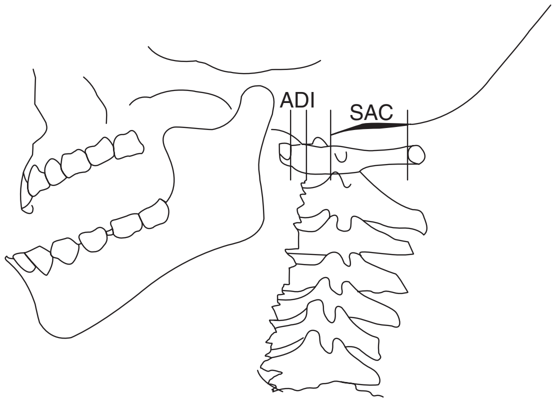

Figure 1 Atlantoaxial Instability: Anatomic Landmarks for Atlanto-Dens Interval (ADI) and Space Available for Cord (SAC)

Treatment

Since AAI can progress over time, at-risk athletes should be followed with regular histories and physical exams.

Special Olympics recommend that athletes with AAI avoid participation in high-risk activities. These include diving, gymnastics, power lifting and squats, alpine skiing, high jump, and pentathlon. They also include butterfly stroke, flip turns, and diving starts in swimming.

These restrictions are controversial since there are no reported cases of patients with asymptomatic AAI (diagnosed by X-ray) sustaining a neurologic injury secondary to sports participation. However, it is still advised that athletes with asymptomatic AAI follow those activity restrictions, but they require no further intervention. They should be followed closely for progression of disease and onset of symptoms.

Patients with symptomatic AAI should undergo MRI evaluation. They should be managed by an experienced neurosurgeon or orthopedist. These athletes will usually need an aggressive surgical approach involving fusion of the vertebra, with ensuing activity limitations.

Kevin D. Walter and J. Channing Tassone

See also Cervical and Thoracic Fractures and Traumatic Instability; Musculoskeletal Tests, Spine; Neurologic Disorders Affecting Sports Participation

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Attention Focus in Sports

Attention refers to the way in which a person allocates his or her mental processing capacity to the task or tasks at hand. The capacity to do mental processing is not unlimited, so effective allocation of attention is pivotal to successful learning and performance. This is especially true in the sports domain, where poor performance is often attributed to errors of attention. A missed free throw in basketball can be caused by distractions from crowd noise; a defensive player in football can be deceived by an opponent to attend to the wrong cues; or the concentration of a tennis player can waver on an easy smash. These are common occurrences in sport that illustrate the connection between control of attention and successful performance. For different types of sports, and tasks within sports, optimal performance depends on the athlete's ability to either focus attention (so as to apply the maximum mental processing resources to a single element of a task) or divide attention (so as to distribute processing resources concurrently between two or more tasks or elements of a task).

Focusing Attention

The ability to focus attention provides a way of ensuring that only the information that is directly relevant to the task at hand gets processed, while other information that is irrelevant, distracting, or deceptive does not. The information that is relevant may come from sources external to the performer (such as targets, teammates, or opponents) or sources that are internal (such as thoughts, mental images, or kinesthetic feedback from sensory receptors in the body). The golfer attempting to make a crucial putt is more likely to be successful if he or she is able to focus attention only on relevant cues (e.g., the position of the hole, the intended point of contact of the putter with the ball, and the speed and trajectory of the movement of the club) and not on irrelevant or distracting ones (e.g., the spectators, the score, or a previously missed putt). The focusing of attention to ensure the processing of only a limited number of cues (from the near infinite array possible) is often termed *selective attention.*

Studies using methods in which the visibility of particular cues is selectively masked and/or eye movements are recorded have revealed that experts in some sports selectively attend to cues that are different from those used by less skilled athletes. In sports such as tennis, highly skilled players attend to, and are able to pick up information from, cues present in their opponent's movement patterns (e.g., the motion of the opponent's arm, the position of the ball toss, and the opponent's position on court), whereas less skilled players generally rely on later ball flight information to know where to move to hit their return stroke. In learning new movement skills, superior results are consistently achieved when learners focus their attention *externally* on the movement outcome (e.g., the trajectory of the ball) rather than *internally* on the mechanics of the movement (e.g., the swing of the arm). Both of these strategies are typically superior to those in which attention is directed to irrelevant cues.

Dividing Attention

In contrast to the golfer, who needs to retain a singular point of attentional focus while putting, the quarterback in football needs to be able to divide his attention contemporaneously between multiple tasks and multiple sources of relevant information. To be successful, he needs to be able to not only control his own running and throwing movements (through attention to relevant internal and external cues) but also simultaneously process information about the current and future positions of both teammates and opponents. Because processing capacity is limited, dividing attention (or processing resources) between current tasks and competing sources of information is generally difficult, although this difficulty is reduced significantly for more skilful/better-trained athletes and in situations in which one or more of the tasks is relatively simple.

Attempts have been made to measure individual differences in the ability to divide attention between competing tasks using self-report instruments (e.g., the NASA Task Load Index), physiological indicators (e.g., pupil diameter, heart rate variability, and event-related changes in the electrical activity in different brain regions), and behavioral measures (involving the concurrent performance of multiple, usually dual, tasks). In the dual-task method, a secondary task (e.g., a reaction time task) is completed at the same time as a primary task (e.g., dribbling a basketball). In such situations, the more skilled athletes typically show superior performance on the secondary task even if their primary task performance is indistinguishable from that of less skilled athletes. With practice, the control of at least some aspects of the primary task may become automatic, or at least require less than the usual levels of attention, effectively freeing processing resources that can then be applied to, and result in better performance of, the secondary task(s).

Controlled and Automatic Processing

The alterations in the attentional demands of different skills that occur with practice highlight the existence of two fundamentally different types of information processing. *Controlled processing*, which is generally thought to be predominant early in learning, is slow, sequential, deliberate, and conscious and consequently requires substantial mental-processing resources. In contrast, *automatic processing*, which is typically associated with highly skilled acts, is rapid, parallel, and involuntary and occurs below the level of consciousness, requiring relatively little of the brain's information-processing resources. Recent research using functional magnetic resonance imaging (fMRI), which permits high-resolution tracking of blood flow changes within the brain, has attempted to determine those areas of the brain most responsible for these different types of processing.

Explicit and Implicit Motor Learning

How and where attention is directed during the learning of a movement (motor) skill can significantly influence the demands on mental processing capacity that are made when the same skill is later performed under competitive pressure. During the controlled processing phase of skill acquisition, *explicit motor learning* occurs when performers encode and store large amounts of conscious, generic knowledge into long-term memory, whereas in *implicit motor learning* the accrual of such knowledge is meager. Performers who learn a movement skill explicitly generally find it more difficult, under conditions of psychological stress or physiological challenge, to divide their attention between performance of the motor skill and conscious processing of other sources of information related to the situation and the anxiety produced by it. As a consequence, the performance of their motor skills can become disrupted. In contrast, performers who learn implicitly appear to find it much easier to divide their attention effectively when multitasking or when faced with the need to perform their motor skills under stressful or challenging conditions.

Implicit motor learning techniques can be used during the early stages of skill acquisition specifically to distract the attention of the learner away from information that can be employed to test hypotheses about the best way to move successfully. This may then effectively reduce the encoding and storage of conscious generic knowledge about the movements. For example, a beginner golfer who makes a series of putts all of which are successful is unlikely to test hypotheses about the best way to move, given that the movement is already highly effective. Consequently, the golfer with error-free performance in learning will store less conscious generic knowledge in long-term memory than a golfer who makes a series of putts that are unsuccessful. The unsuccessful golfer is likely to deliberately test many hypotheses about how to move as he or she searches for an effective putting technique and will consequently generate and store large amounts of conscious generic knowledge. Developing a variety of strategies to optimize attentional focus for both learning and performance of motor skills presents an ongoing challenge for sports scientists and coaches alike.

Bruce Abernethy and Rich S. W. Masters

See also Arousal and Athletic Performance; Sport and Exercise Psychology

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Avascular Necrosis of the Femoral Head

Avascular necrosis (AVN), which is also known as osteonecrosis, aseptic necrosis, ischemic necrosis, and osteochondritis dissecans, is a pathological process that results in the death of bone tissue in the affected area. Many medical conditions and treatments have been linked to AVN.

The exact mechanism that causes AVN is not well understood. The process leading to AVN involves compromise of the bone vasculature, which leads to the death of bone and marrow cells and ultimately to mechanical failure of the affected bone. The process of AVN is often progressive and will result in joint destruction within 3 to 5 years if left untreated.

Prevalence

The exact prevalence of AVN is not known. Each year, 10,000 to 20,000 new cases are diagnosed in the United States. Men are eight times more likely than women to be diagnosed, and the average age at diagnosis is less than 40 years.

Causes

A number of traumatic and nontraumatic factors have been linked to AVN. Greater than 90% of reported cases of AVN are due to glucocorticoid use or excessive alcohol intake.

The precise cause of AVN is not completely known. It is thought to result from a combination of metabolic factors, mechanical stress, and local factors in the affected joint that alter the blood supply. AVN most likely begins from an interruption of blood supply to that area, leading to weakened bone that will collapse if stressed.

Glucocorticoids

Many studies have been done that link glucocorticoid use with an increased risk of developing AVN. The exact mechanism by which glucocorticoids increase this risk is not known. One proposed mechanism is that steroids alter the circulating lipids in the blood supply, leading to microemboli that block the arteries supplying the bone. Another theory proposes that steroids cause changes in venous endothelial cells, leading to stasis of blood and increased pressure within the bone, which eventually leads to necrosis.

Patients treated with prolonged courses of high-dose glucocorticoids seem to be at the greatest risk of developing AVN. Patients receiving short-term steroids, including pulse-dosing and steroid injections into the joint, rarely develop AVN.

Alcohol

Excessive alcohol intake and the development of AVN have been well studied in the literature. Studies suggest that fat emboli, venous stasis, and increased cortisol levels associated with alcohol intake contribute to the development of AVN. Studies have clearly documented that a clear dose–response relationship exists between alcohol intake and risk of developing AVN. The more alcohol consumed regularly, the more likely a patient is to develop AVN.

Trauma

Fracture or dislocation of a bone may cause damage to the blood vessels inside the bone. For example, fractures in the subcapital region of the femoral neck (the femur is the thighbone that connects the hip to the knee) frequently interrupt the major part of the blood supply to the head of the femur, which can lead to AVN.

Other Risk Factors

Many other medical conditions have been associated with AVN. These include, but are not limited to, sickle cell hemoglobinopathies, lupus, Gaucher disease, chronic renal failure, pancreatitis, hyperlipidemia, HIV infection, and gout. In addition, there are two types of AVN that are seen only in children. The first is idiopathic osteonecrosis of the femoral head, which is known as Legg-Calvé-Perthes disease (please see separate entry for more details), and the second is osteonecrosis occurring in children, which is associated with a slipped capital femoral epiphysis (please see separate entry for more details).

Symptoms

The most common presenting symptom of AVN is pain. Groin pain is the most common complaint in patients who have AVN of the femoral head. Thigh pain and buttock pain are also associated. Most patients complain of increased pain when bearing weight on the affected joint and during movement of the joint. Two thirds of patients also complain of pain during rest, and one third of patients complain of night pain. Many patients do not present until late in the disease process because pain is not always present in the beginning stages.

Location of Avascular Necrosis

The most common location of AVN is the anterolateral femoral head. AVN has also been seen in the humeral head (the humerus is the arm bone that connects the shoulder to the elbow), femoral condyles, proximal tibia (the top of the shinbone), vertebrae in the spine, and small bones of the hand and foot. Some patients have disease on only one side of the body, but many patients present with disease on both sides (bilateral). Bilateral disease is most commonly seen in disease of the hips, knees, and shoulders.

Diagnosis

When the symptoms suggest AVN, a complete physical exam and imaging studies are done to help make the diagnosis. Findings on physical exam are usually nonspecific. Patients may have pain and some limitation in the range of motion of the affected joint. A limp may be present as the disease progresses to the later stages. Some patients with AVN will have a normal physical exam with no symptoms.

Imaging studies including X-rays, bone scans, and magnetic resonance imaging (MRI) are helpful in making the diagnosis and also to classify and stage the extent of disease. X-rays are the first step in imaging studies. Evaluation of suspected AVN of the femoral head should begin with anterior-posterior and frog-leg views of the hips. It is important to know that X-ray findings can remain normal for months after symptoms of AVN pain begin.

Bone scans are helpful to further evaluate patients with suspected disease who have normal X-rays, unilateral symptoms, and no known risk factors for AVN. The bone scan determines areas of active bone turnover and will show an area of active turnover surrounding a cold area or "dead spot" where bone has died due to AVN. This finding on bone scan is known as the "doughnut sign."

Magnetic resonance imaging (MRI) is much more sensitive than plain X-rays or bone scans and can detect changes early in the course of the disease if the other imaging reports have been negative and AVN is highly indicated.

The diagnosis of AVN is a clinical diagnosis based on symptoms and findings on imaging. Unfortunately, there is no single simple test to determine if AVN is or is not present. The doctor must look at a number of factors and rule out other possible causes before making the diagnosis.

Classification and Staging

Classification and staging of AVN are based primarily on radiographic findings. The greater the extent of bone involved, the more serious the disease and the higher the stage. Stage 0 is normal diagnostic studies and Stage 4 shows late changes in the affected joint.

Treatment

The goal of treatment is to preserve the native joint for as long as possible. The ideal treatment for AVN remains controversial in the current orthopedic literature. There are four therapeutic options: (1) conservative management, (2) joint replacement, (3) core decompression with or without bone grafting, and (4) osteotomy.

Conservative management involves bed rest, partial weight bearing with crutches, weight bearing as tolerated, and the use of nonsteroidal anti-inflammatory agents for pain management. This approach has generally not helped stop the progression of disease. Joint replacement (e.g., a total hip replacement for a patient with AVN of the femoral head) has also been shown to be somewhat ineffective for AVN. Patients who have joint replacement because of AVN tend to do more poorly than patients who have joint replacement for other reasons. Total joint replacement of the shoulder for AVN has been shown to be more successful than hip or knee joint replacement.

Core decompression for AVN was initially used as a diagnostic tool to measure bone marrow pressure and to get bone marrow biopsy specimens. Doctors began to notice that patients had symptomatic pain relief after the "diagnostic" procedure and began to use it as a type of treatment.

Osteotomy is a "joint-sparing" technique that has been used to treat AVN, primarily of the femoral head. The goal of this treatment is to move the area of necrosis away from the major transmitting area of the acetabulum and to redistribute the weight-bearing forces to healthy cartilage and bone. Overall, osteotomies have been successful in treating later-stage AVN of the femoral head.

The optimal treatment for AVN is yet to be determined. The decision depends on the joint involved, the extent of disease, and the other risk factors present in the individual patient.

AVN and Sports Medicine

An athlete who presents with pain in a joint area should be thoroughly evaluated and AVN ruled out, especially if the athlete has any or a combination of the above-listed risk factors,.

Athletes who have AVN, which occurs most commonly as a result of trauma in athletes, will need close follow-up after diagnosis and treatment. These athletes will need comprehensive physical therapy after recovery, especially if they undergo surgery. All athletes should be counseled about lifestyle factors that could put them at higher risk for AVN.

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See also Legg-Calvé-Perthes Disease; Slipped Capital Femoral Epiphysis

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Avulsion Fractures

Avulsion fractures are sports injuries that may occur at any age but are frequently seen in adolescent athletes. They usually involve a fracture of a bone at the insertion site of a tendon or ligament. The mechanism of these injuries is often the exertion of a force on a bone that leads to the fracture and subsequent separation of a piece of the bone from the skeleton. The excessive stretching of the muscle that attaches to an incompletely fused piece of bone can also create an avulsion. The athletes who suffer the most from these injuries are sprinters, jumpers, and those involved in sports with rapid stops and starts, such as football. Avulsion fractures occur most often in athletes aged 14 to 17 years, and with the emergence of competitive athletics among children and teens, these injuries are becoming more common.

Mechanisms

Avulsion fractures can occur at practically any site on the skeleton. The pelvis is a common location as the major muscle groups of the lower extremity attach to small processes on the pelvic bones. The hamstrings commonly generate avulsion fractures, and they attach to the ischial tuberosity, a swelling of bone on the ischium of the pelvis. These muscles contract forcefully during sprinting or jumping. The mechanism for injury is the initial contraction in a sprint, during which the muscles generate enough force to separate a piece of the ischial tuberosity from the pelvis. Similarly, the sartorius muscle, which attaches at the anterior-superior iliac spine of the pelvis, contracts during knee and leg flexion, which makes avulsion possible during running and jumping. Conversely, the rectus femoris is a leg muscle involved in extension of the knee and hip flexion. It can injure the anterior-inferior iliac spine during those same activities. The abdominal muscles can cause avulsion of the iliac crests of the pelvis during exercise as well. This occurs with severe abdominal contractions or rapid twisting of the upper torso. These pelvic injuries significantly limit overall activity, as the lower extremities need to be rested after these types of insults.

Apart from the pelvis, long bones such as the femur and the ulna are also susceptible to avulsion fractures. The iliopsoas muscles can avulse pieces of the lesser trochanter of the femur during rapid hip flexion. The olecranon of the ulna is the insertion point of the triceps brachii muscles. The olecranon can be damaged with repeated, forceful throwing motions, primarily seen in young pitchers (Little League elbow). The glenoid of the scapula is also vulnerable to avulsion from the biceps tendon's insertion at the labrum during rapid arm flexion, as seen with tackling in football. Upper extremity injuries are serious and require long rehabilitation. Nevertheless, they are much rarer, as adolescents tend not to have as well-developed upper extremity as lower extremity muscles.

Avulsion fractures at large joints, such as the knee, are often caused by extrinsic forces on the ligamentous structures. In the knee, the lateral collateral ligament (LCL) and the anterior cruciate ligament (ACL) cause these injuries after severe internal rotation of the tibia with a flexed knee or other mechanisms of knee injury such as direct trauma. One such injury, the LCL-induced avulsion fracture of the tibia, "Segond fracture," is often associated with ACL tear when present in adults but causes isolated avulsion fractures in adolescents. In the case of ACL-induced tears, the tibial eminence, a wide, depressed area on the anterior, proximal portion of the tibia, is avulsed (left photo next page). Avulsion of the proximal fibula is most commonly due to forces exerted on the bone by the LCL and biceps femoris tendon, commonly seen when ACL and posterior cruciate ligament (PCL) tears occur. The presence of the "arcuate" sign on the X-ray is an important predictor of the success of surgical reconstructions of these knee ligaments. If an avulsion of the fibula is present but not identified and addressed, there is an increased likelihood of failure of the reconstruction, leading to chronic knee instability. Nevertheless, with proper immobilization and rehabilitation, chronic instability can be averted.

Avulsion fracture of the tibial eminence at the anterior cruciate ligament insertion of the tibia

Source: Authors.

Avulsion fracture of distal fibula at the insertion of the anterior talofibular ligament

Source: Authors.

Smaller joints and bones, such as the ankle and the fifth metatarsal, are affected as well. The common ankle sprain, which is caused by excessive inversion of the foot, can lead to an avulsion fracture as well. The anterior tibiofibular ligament is the first ankle ligament to tear in common ankle sprains and has been known to avulse pieces of the distal fibula and tibia (right photo). Avulsions of the proximal aspect of the fifth metatarsal are seen in cases of severe plantarflexion (toe-off) and inversion of the ankle. The attachment of the lateral plantar aponeurosis is supposed to be the culprit in these cases, as in sprinting. This type of metatarsal fracture is effectively resolved with conservative therapy. It is important to differentiate this injury from Jones fracture, which often requires surgical repair. From these examples, it is clear that avulsion fractures occur at many sites throughout the body and thus are important pathologies to keep in mind when assessing an injured athlete.

Presentation

Athletes who have avulsion fractures present with localized pain, swelling, limited range of motion, or sudden loss of function of the affected area. They often report a snapping sound or sensation accompanying a movement of significant effort. After the incident, there is usually severe tenderness to palpation, as well as an increase in discomfort with movement of the affected muscle group. The injured athlete will favor a position that maximally stretches the muscle.

Diagnostic Studies

Radiographs of the affected area are routinely ordered. Imaging of the contralateral bone can be helpful in confirming an avulsion fracture, especially in growing children. Initial films do not always capture the fracture, as the fracture may be only minimally displaced or indistinguishable from normal, unfused bone in a child. Repeat films may be required a few weeks after injury for confirmation, as time will allow soft tissue changes to accentuate the fracture. Magnetic resonance imaging is not routinely required and is only used when further evaluation is needed.

Treatment

Treatment for avulsion fractures begins with rest. Athletes need to remain on bed rest or have their movement considerably limited in the early stages of recovery. It is important to place the involved muscle group in a relaxed position and ice the injured area to limit soft tissue swelling. Pain relievers will help keep patients comfortable during recovery. Once the pain has subsided, the patient is permitted to gradually increase the level of activity involving the affected musculature. After full range of motion without pain is achieved, the patient can begin retraining the muscles. A stepwise program that involves resistance exercises for the muscles in isolation is recommended initially. The timetable for return depends on the location and severity of the injury; reports of return to normal activity 4 weeks to 4 months after initiation of a proper rehabilitation program have been documented. Fortunately, good to excellent results can be achieved for most athletes using a nonoperative rehabilitation program.

The role of surgery as a treatment modality is not well defined. Evidence-based criteria for surgical intervention are not yet established, but as a guideline, when a bone fragment is displaced greater than 2 cm, it often requires surgical fixation. Surgical intervention can decrease the likelihood of nonunion of the fragment, preventing chronic pain and functional disability.

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See also Anterior Cruciate Ligament Tear; Fractures; Lower Back Muscle Strain and Ligament Sprain; Rhomboid Muscle Strain and Spasm

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B

Back Injuries, Surgery for

Athletes with back injuries are commonly divided into two groups on the basis of diagnosis: (1) those with stress fractures and (2) those with lumbar disk herniations. Stress fractures of the lumbar spine are termed *spondylolysis*. Spondylolysis is caused by repetitive hyperextension forces on the spine in an area termed the *pars interarticularis*. The *pars* refer to the part, and *interarticularis* refers to the bony area connecting the facet joints. Hyperextension causes tension in this area of the spine, and the repetitive motion eventually leads to a fatigue crack in the spine. The incidence of spondylolysis in the normal population is believed to be around 8%, with a higher incidence in the athletic population. Athletes who are involved in activities that entail hyperextension of the spine are at a greater risk of developing this injury. Gymnasts who perform many back-spring activities and down linemen in football, who rise from a forward stance and are pushed back, represent the athletes who most commonly sustain this injury.

Patients with spondylolysis generally present with significant low back pain related to their sports activities. The examination of these patients will indicate pain in the affected area with hyperextension. Plain X-rays may aid in the diagnosis; however, many times, a computed tomography (CT) scan or magnetic resonance imaging (MRI) is required to make the definitive diagnosis. These studies reveal a fracture of the pars interarticularis, which sometimes is acute; however, often there is evidence that these are long-standing injuries that have recently become symptomatic. Nonoperative treatment of these patients is generally sufficient for resolution of symptoms and return to full sporting activities. It revolves around physical therapy working on strengthening the core musculature of the body and stretching to improve flexibility. The use of bracing is indicated in those patients who have specific symptoms such as pain and spasm of the back. Surgical treatment is deemed appropriate in long-standing stress fractures in which the athlete is unable to become painfree despite physical therapy and bracing.

Herniation of the lumbar disk is the other common type of sports-related back pain; disk herniation is brought about by an increase in pressure and strain on the intervertebral disk. This increase in stress causes a weakening of the ligament surrounding the disk, which results in weakening and failure of the *annulus,* or outer fibrocartilaginous rings, of the disk surrounding the *nucleus pulposus* at the center. The resulting outpouching of the pulposus material causes back pain; however, most symptoms are caused by the disk area that has herniated exiting and touching a nerve root. The resultant pressure on the nerve root leads to radiculopathy.

Pressure against a nerve root causes irritation in the nerve root, which can lead to pain signals down the leg from the irritated nerve, weakness in muscles innervated by that nerve, numbness in areas that are innervated by that nerve, and resultant reflex changes. On examination, the athlete will present with significant pain and, occasionally, listing to one side, which is the body's way of splinting the affected area. Nerve tension signs are physical exam findings that are seen when the nerve is stretched, causing irritation due to pressure by the herniation, as in a straight leg raise test.

Surgical Treatment

Surgical treatment for spondylolysis depends on the location of the fracture. The most common location of a stress fracture is the fifth lumbar vertebra, which is the last bone before the sacrum. Surgical treatment of a stress fracture in this area entails fusing of the bone with the sacrum, termed an L5-S1 fusion. The goal of this operation is to prevent motion at the site of the stress fracture by making that portion of the spine stiff. A *fusion* occurs when two bones that move together in normal circumstances are surgically made to become one bone. This is performed by creating a new bone growth by way of bone grafting. The bones of the fifth lumbar vertebra are made to grow together with the bones of the sacrum by adding a bone graft. Once they become a solid area of bone, they will not move separately, and hence, the fracture cannot move; this eliminates the source of pain for the patient. Surgeons will occasionally use spinal instrumentation in the form of screws and rods during surgery to help internally immobilize the bones. Bones tend to fuse together if there is no motion, and the bone graft matures into solid new bone; local screws into the bone connected to rods help immobilize the area and improve the chance of fusion.

Occasionally, spondylolysis requiring surgical treatment will occur higher in the lumbar spine, such as in the third or fourth lumbar vertebra. In these instances, surgical treatment is aimed at fixing the fracture because motion loss in these areas is more detrimental to an athlete. This procedure entails directly cleaning the area of spondylolysis of scar tissue and placing a bone graft in the fracture site. This is termed a *direct pars repair* and is usually supplemented by a screw across the fracture site to hold the fracture still until the bone graft matures and solidifies.

Surgical treatment of a lumbar disk herniation is performed in a minimally invasive manner by using a microscope and doing a limited surgical dissection. The surgeon makes a small incision over the back in the affected area and moves the muscles out of the way at the correct level. The surgeon then performs a small laminotomy, in which the bone and the ligament are removed to enter the area where the spinal nerves are located. The surgeon then identifies the spinal nerves, gently moves the affected nerve out of the way, and removes the herniated disk fragment. In general, the herniated fragment represents a small overall piece of the disk, and hence its removal does not affect the entire disk.

After Surgery

Recovering from surgical treatment of spondylolysis requires 3 months of absence from any athletic activity. In the first 6 weeks, the patient is required to wear a low-contact, hard-shelled brace during upright activities. After the sixth week, the athlete can start controlled physical therapy aimed at core strengthening, pars spinal muscle strengthening, and lower-limb flexibility. Return to noncontact sports may begin after 3 months; but in general, contact sports require a total of 5 months before return to play. Disk herniation surgery usually requires a minimum of 6 weeks off to minimize the complications of reherniation. Physical therapy may be instituted at 2 weeks after surgery and focuses on core strengthening and flexibility. Return to contact sports may begin after 3 months.

Daniel Hedequist

See also Cervical and Thoracic Fractures and Traumatic Instability; Cervical and Thoracic Spine Injuries; Lower Back Injuries and Low Back Pain; Lower Back Muscle Strain and Ligament Sprain; Slipped Disk; Spinal Cord Injury

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Badminton, Injuries in

Badminton is a court-and-racquet sport requiring high levels of cardiovascular endurance, strength, and dexterity. As Olympians, the athletes participating in this event have elite training and the highest levels of the above characteristics. As a result, they are able to strike the projectile in this game at extremely high velocities. The nature of this sport leaves the participants vulnerable to injury categories that include those related to high-speed projectiles, acute lower and upper extremity trauma, chronic overuse injuries of the upper and lower extremities, and various other injuries. This entry highlights the game and history of badminton and those injuries specific to the game of badminton and others related to racquet sports in general.

The Game

Badminton is a racquet sport played by either two opposing single players or two opposing pairs, on a rectangular court with a net dividing the sides equally. This sport differs from most other racquet sports in the use of a shuttlecock instead of a ball. The shuttlecock has feathers that create a significant drag, decelerating the projectile much more quickly than the traditional projectiles. These projectiles are struck with a lightweight racquet that can be swung quickly, easily providing the force to create an extremely fast-moving object. The objective of the game is to strike the shuttlecock in such a manner as to have the shuttle strike the ground in the opponent's territory.

Equipment

Badminton racquets are lightweight, with top-quality racquets weighing between 80 and 90 g, including the strings. They are composed of many different materials, ranging from carbon fiber composite to solid steel, which may be augmented by a variety of materials. For many years, all badminton racquets were made of wood, which is fairly light and durable. However, carbon fiber composite, such as aluminum, can be much lighter and more durable and, most important, extremely stiff. This stiffness decreases the amount of kinetic energy lost to the racquet when striking the shuttlecock. The strings of the racquet are usually around 0.25 millimeter in width, and the tension ranges from 80 to 130 newtons.

The *shuttlecock*, or birdie, is cone-shaped with a cork base surrounded by a leather or synthetic cover. From this base, a cone-shaped ring of goose feathers arises, creating the drag of this projectile. As in squash, the shuttlecocks come in a range of speeds that are color coded (green is slow, blue is fast, and red the fastest).

Badminton shoes should be comfortable and lightweight, with soles that provide good traction. Unlike tennis and running shoes, the soles should not be elevated. An elevated shoe increases the risk of ankle sprain in this game, which requires very forceful lateral movements.

Injuries

Injuries discussed in this entry will be divided into three categories. First are general injuries related to court games. These tend to result from repetitive stress to individual body parts, leading to overuse injuries or acute injuries related to sudden direction change and other forces applied during play. Second are overuse injuries that are particular to the game of badminton. Third are injuries related to high-speed ballistics. Treatment of these conditions is not covered here since the treatments are generally standard and are covered in other, related entries.

Overuse Injuries in Racquet Sports in General

Most racquet sports are fast-paced matches in which the players start and stop suddenly and change direction, often while swinging racquets of variable weight and size. Injuries generally sustained under these circumstances include both soft tissue and bony injuries to the feet, legs, knees, hips, shoulders, elbows, wrists, and hands. When a muscle—for instance, the gastrocnemius—is loaded concentrically and eccentrically hundreds of times during a game, the weakest point will incur the most damage. For adults, this point is the tendon or the point where the tendon meets the muscle. This includes the Achilles tendon, which is loaded when the athletes push off the ground or land on their toes, which occurs often in badminton (often the athletes are "on their toes" for the entire event). Achilles tendinosis is a common condition in racquet sports. The patellar and quadriceps tendons are loaded with each jump or sudden stop. This results in the common diagnosis of patellar or quadriceps tendinosis. The shoulder and elbow have common overuse syndromes with similar mechanisms, including rotator cuff tendinosis and epicondylitis, respectively. Bony injury can also occur from chronic loads, as in stress reaction where the bone is weakened and, occasionally, fractures from recurrent stress of impact. Joints can be injured as well through chronic stress, as in osteochondritis dissecans, where microstress can cause permanent injury to the cartilage that protects the joints. Awareness of these injuries with limitations of repetitive motions and good injury prevention programs can decrease the incidence of these injuries.

Acute Racquet Sports Injuries

The majority of acute injury in racquet sports is related to the sudden starts and stops, direction change, and jumping involved with the particular sport. Multiple athletes sharing the same court space can increase the risk of blunt trauma, of ankle-type injuries (when one athlete inverts his or her ankle on the other), or of being struck directly with the racquet. The majority of acute injuries involve the lower extremity. In the case of patellar tendon and Achilles tendon rupture, the cause is likely related to the pattern of injury described above, leading to weakened tendons. They are both surgical problems. Other acute injuries in the ankle include fractures and sprains of the stabilizing ligaments. In the knee, twisting injury can lead to tearing of the meniscus and the anterior cruciate ligament. Less commonly, the racquet-sports athlete can have an acute upper extremity injury to the shoulder, elbow, or wrist, including muscle and tendon injury. This may also include rare rotator cuff strains.

Badminton-Specific Injuries

Injuries specific to badminton are upper extremity injuries. Players swing extremely lightweight racquets and use wrist strength to produce quick racquet speed. This "flicking of the wrist" puts significant strain on both the wrist flexor group of muscles and the wrist extensors, causing muscle and tendon tearing. The treatment of these, generally, overuse injuries includes prevention, activity modification, bracing and rehabilitation, and, rarely, surgery. In terms of prevention, the players are encouraged to engage in general upper extremity strength work, focusing on wrist strength, in addition to quality periods of rest and recovery. Once the injury occurs, if it is mild, players can increase their recovery periods and consider bracing, such as a counterforce brace. If the injury is significant, a prolonged period of rest is indicated, from a few days to several weeks, depending on the severity. Rehabilitation will again focus on regaining wrist strength, as well as a number of other modalities provided by the player's athletic trainer or physical therapist. In rare cases of severe recurrent epicondylitis, a debridement procedure can be considered.

Projectile Injuries

Although relatively rare, shuttlecock-related injury can occur to soft tissue. The most devastating and preventable injuries are ocular. If the eye is struck directly by the shuttlecock, a player can sustain permanent visual loss. If the globe of the eye is ruptured, the cornea injured, the lens detached, the retina detached, or any number of other critical structures injured, the player can lose vision. For this reason, it is critical that all levels of players in high-speed racquet sports be required to wear eye protection.

Gian Corrado

See also Eye Injuries; Overtraining; Tennis and Racquet Sports, Injuries in; Wrist Injuries

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Baseball, Injuries in

In the 1960s, Nolan Ryan, a professional baseball pitcher, began lifting weights as part of his physical conditioning regimen. At that time, most people subscribed to the belief that strength training with weights was deleterious to the baseball player's body. Especially with regard to pitchers, it was believed that weight-lifting programs would produce muscle growth that would impede the player's movements and biomechanics. But within a decade, advancements in sports medicine disproved what everyone had thought to be true. By the end of the century, this transformation had a lasting effect, the likes of which almost no one perceived even a few years earlier.

Baseball is a team sport that requires the individual athlete to run, hit, and throw. Under normal conditions, these activities do not generally tax the human body. But under the conditions of a baseball game, the requirements to throw a ball, swing a bat, and run around the field of play put unusual distress on players' joints and muscles. As a result, there has long been a focus on training methods that help prevent injury. Yet baseball, from the youth to the professional levels, has over time also become increasingly focused on performance.

The shift to performance enhancement poses enormous challenges for ballplayers and the sports medicine practitioners who attempt to keep them in playing condition. Despite the mounting existence and availability of performance-enhancing substances, the care and conditioning of ballplayers was essentially the same in the 1960s as it was at any time prior. But as people in the ranks of medical science and technology began to use their skills to perform more highly specialized work, the product of their work was increasingly applied to baseball and vice versa.

There may have been no greater a period of significant advancements in baseball-specific sports medicine than that which occurred during the two or so decades beginning around 1960. For instance, in 1966, the future Hall-of-Fame pitcher Sandy Koufax abruptly retired due to injury sustained from overuse of his throwing arm. The fastballs and curve balls he threw en route to recording 382 strikeouts in 1965 forced him to retire at age 30, on the heels of the last of his three Cy Young Awards. Throughout his 12-year career, which included winning 25 games three times, the bone spurs, scar tissue, adhesions to the cartilage covering the elbow, circulatory problems in his left (throwing) hand, and arthritis that he developed were treated with ice baths, massage therapy, and ointments. For Koufax and other ballplayers through that era, preventive treatments superseded curative treatments; the player tended to retire when the latter proved no longer effective.

But around the same time, physicians began to pay attention to injuries and ailments in ballplayers of all ages and skill levels. A body of research on baseball-related injuries and ailments—mostly associated with pitching—began to emerge from clinical practices, one of which was the orthopedic practice run by Dr. Robert Kerlan. Kerlan, who as the first team physician in the history of the Los Angeles Dodgers recommended to Koufax that continuing his career past the 1966 season could result in permanent arm damage, later formed a partnership with Dr. Frank Jobe. Together, they devised innovative treatments and procedures that were a significant contribution to the game of baseball. By the mid-1970s, Jobe had invented a surgical procedure that could reconstruct a damaged elbow. The procedure to repair a torn ulnar collateral ligament by harvesting a nonessential tendon from a ballplayer's nonthrowing side wrist, followed by 18 months of recovery, allowed the then Dodgers' pitcher Tommy John to resume a playing career in which he would eventually win a total of 288 games—164 of which came after the operation that today informally bears his name.

Since then, numerous other surgical procedures have been developed to remedy injuries in the shoulder, elbow, and wrist, as well as at other bodily sites that have been compromised by injury.

Common Injuries and Health Care Concerns

The shoulder region and arm are the sites most often considered in the context of baseball injuries. Particularly for pitchers, the repetitive and high-energy forces of the throwing motion place progressive stress on the stabilizing structures of the shoulder. This can lead to instability, especially in the rotator cuff and shoulder capsule ligaments. While an intensive strengthening program can encourage structural stability and proper biomechanics, tissue damage in the shoulder sometimes requires anatomical repair through surgical intervention, followed by a postoperative rehabilitation program.

Yet all regions of the body must be given proper care and attention during baseball-related activities. Because baseball is a sport that involves the use of the entire body, all areas, including the shoulder region and arm, are susceptible to injury: head, neck, and face; thoracic through coccygeal spine; thorax and abdomen; hip and pelvis; thigh, leg, and knee; and lower leg, ankle, and foot. Given baseball's continuous enormous popularity in the United States, there is an overall increased incidence of injury as more people, especially youth, participate in organized and spontaneous baseball games.

Acute baseball-related injuries tend to be caused by the impact of being hit by a ball or bat or by collision and sliding. Severe injuries—and sometimes fatalities—are often the result of blows to the chest and head. This has been a cause of concern in all levels of baseball. So too is the fact that adolescent pitchers sustain chronic injuries to the shoulder and the elbow as a consequence of throwing too many pitches without proper recovery and throwing certain types of pitches. The literature that reports on the veracity of these claims is mixed, although some large-scale investigations have concluded that baseball has a high incidence of injury associated with it, particularly for pitchers who throw with the sidearm style.

But more recently, the prevalence and use of performance-enhancing drugs (PEDs), including steroids and herbal dietary supplements, has been of mounting concern in baseball circles. The abuse of PEDs, especially anabolic-androgenic steroids, is the fastest-growing form of drug abuse in the United States, according to the Food and Drug Administration. On a very basic level, these steroids are the synthetic derivatives of the naturally occurring male anabolic (tissue building) hormone testosterone. By duplicating the effects of testosterone, these steroids, either injected or taken orally, have the capacity to encourage increased muscle strength and muscle growth. This allows the athlete to train harder for longer periods of time. Their frequent enhancement of performance and social recognition, their apparent use by some professional baseball players and other elite athletes, and the likelihood of diminishing results once usage is stopped create an incentive for the user to continue using PEDs. Yet those who persist in taking these substances often evade the fact that these PEDs can cause serious physical and psychological side effects and that injury rates can result from increased loads on bones and joints.

Performance Enhancement and Injury Prevention

Steroids may, at present, be highly equated with performance enhancement, but there are other means through which ballplayers can choose to prepare and modify their bodies ahead of competition. Perhaps the most effective way through which to prevent injury is to develop physical fitness. Athletic trainers and, increasingly, strength and conditioning coaches in many instances now work with ballplayers to devise complete physical conditioning programs. These usually include a regimen of cardiorespiratory fitness, muscular strength and endurance fitness, flexibility, and nutrition and therein variously consist of general and sport-specific conditioning. An increasing number of baseball teams, from youth to professional, have instituted such full-fledged strength and conditioning programs to assist ballplayers in their preparatory and competitive efforts. And some of these programs have increasingly been aided by the advent of sport psychology, which complements the physical conditioning by giving attention to the mental aspects of performance. That is, a good many ballplayers today use modes of training and conditioning that half a century ago had been exceptions to the norm.

For all of these impressive changes that have taken place in and around baseball during that span of time, it stands to reason that injury rates have decreased and careers have been prolonged. But this is too simple an assumption, in large part because the game has changed dramatically in a short time.

In an era of conditioning, pitch counts, player match-ups, a heavy dependency on relief pitchers, the evolution of free agency, player development and procurement strategies, incentive clauses in contracts, and advances in orthopedic surgery and physical therapy, fans marvel at the endurance and durability of modern-day pitchers, who rarely succeed in reaching double digits in complete games during a season. Although there were 29,101 complete games thrown between the 1960 and 2007 Major League Baseball seasons, only 16% of those were pitched after the 1989 season.

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See also Dietary Supplements and Vitamins; Doping and Performance Enhancement: Historical Overview; Performance Enhancement, Doping, Therapeutic Use Exemptions; Principles of Training; Shoulder Injuries

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Basketball, Injuries in

Basketball is an organized collision sport that is played by millions of people worldwide. Developed in 1891 by Dr. James Naismith as a way to keep his physical education students occupied, basketball has seen an incredible amount of change over time. Originally played with a soccer ball, peach basket, no dribbling, and nine players to a side, the game has evolved to become the fast-paced and dynamic sport it is today. Basketball requires a high level of hand-eye coordination, as well as explosive jumping, cutting, and running maneuvers. As a result, lower extremity injuries to the knee, ankle, and foot are expected. In addition, head injuries, sudden cardiac events, and upper extremity conditions commonly occur. Injury rates for basketball athletes will continue to rise as the popularity of the sport grows.

Epidemiology

Basketball is the third most popular sport offered by U.S. high school athletic programs. Nearly 1 million high school boys and girls participate during each school year. Even among adults, there are more than 500,000 yearly visits to physician offices and emergency rooms for basketball injuries. The injury rates of males and females appear to be equal. When competing in games, athletes are approximately two times more likely to be injured than in the practice setting. Sixty percent of all injuries occur in the lower extremity. The most common areas injured are the ankle, foot, knee, head, and hand. Ligament sprains, muscle strains, contusions, and fractures are the most frequent diagnoses.

Knee Injuries

Knee Sprain

There are four main ligaments of the knee. The medial collateral ligament (MCL) and lateral collateral ligament (LCL) are located on the inner and outer sides of the knee, respectively. Conversely, the anterior cruciate ligament (ACL) and the posterior cruciate ligament (PCL) are present within the knee joint. While direct contact to the knee causes most MCL, LCL, and PCL sprains, noncontact injuries after twisting or cutting movements are notorious for causing a torn ACL. Hearing or feeling a "pop" is a classic description of a sprained ACL. Frequent symptoms include swelling within the knee joint and a feeling of instability. Often, associated structures such as the meniscal cartilage and the MCL are injured along with the ACL. Currently, the gold standard for diagnosis of an ACL sprain is a magnetic resonance imaging (MRI) study. When an ACL sprain occurs in isolation, surgical reconstruction is performed for athletes who desire a return to cutting and pivoting sports. The management for all other isolated knee ligament sprains is nonsurgical.

Meniscal Tear

Meniscal tears are an injury to the cartilage of the knee. The meniscus is the cartilage that is attached to the tibia (shinbone) and serves primarily as a shock absorber. Meniscal tears are classically produced by twisting movements at the knee. Pain at the joint line and swelling are common symptoms of a meniscal tear. When mechanical symptoms such as locking or catching of the knee begin, the management of this condition becomes surgical. Depending on the location and quality of the tear, the injured meniscal cartilage can be repaired or resected. For athletes without mechanical symptoms, either nonoperative or operative treatment is appropriate.

Patellar Tendinitis

With a nickname such as "jumper's knee," it is not surprising that patellar tendinitis afflicts a great number of basketball players. The patellar tendon attaches the kneecap to the tibia. It is under the most stress during knee extension, when the tendon is subjected to large weights while jumping and landing. A rise in the volume or the intensity of play, such as early in a season, is a common cause for patellar tendon injuries. Pinpoint pain over the patellar tendon and pain with running and jumping are frequent symptoms. Rest from offending activities, frequent icing, and patellar strapping are initial treatment options.

Ankle and Foot Injuries

Ankle Sprain

Ankle sprain is the most common injury found in basketball players. Nearly 40% of all basketball injuries are to the ankle and foot. Given the amount of running and cutting, as well as the potential for landing on opponents' feet, this is not surprising. An ankle sprain is a stretch or tear of the ligaments that attach the lower leg bones to the bones of the feet. The outer ankle ligaments are affected far more often than those on the inner aspect of the ankle. Pain, swelling, and bruising are frequent consequences of ankle sprain. X-rays may be necessary to exclude a fracture in certain circumstances. Initial treatment includes *r*est, *i*ce, *c*ompression, and *e*levation (RICE) of the ankle. Early attempts at improving range of motion by the prevention of swelling are critical to an efficient recovery. Ankle taping and ankle braces are used to protect an injured ankle or prevent a future sprain.

Achilles Tendinitis

The Achilles tendon attaches the calf muscles to the calcaneus (heel bone). It facilitates heel raising and, thus, is essential in jumping. Achilles tendinitis is an overuse injury that is frequently triggered by increases in the volume and intensity of play. Pain during heel elevation or jumping and pain directly over the Achilles tendon are frequent symptoms. Along with relative rest and icing to initially treat Achilles tendinitis, specific strengthening exercises are crucial to long-term treatment.

Achilles Tendon Rupture

Basketball athletes are notorious for experiencing an acute rupture of the Achilles tendon. While typically pushing off of their toes, the athlete experiences a sensation such as being kicked in the heel. Difficulty pointing the toes or palpation of a large defect in the tendon is indicative of a complete Achilles rupture. Nonoperative management avoids potential wound complications from surgery; however, some physicians advocate surgical repair as it may reduce the risk of repeat rupture of the Achilles tendon.

Jones Fracture

A Jones fracture is an acute fracture at the proximal (closest) aspect of the fifth metatarsal bone. Analogous to ankle sprains, Jones fractures develop after a rolling injury of the foot and ankle. A foot fracture is suspected, though, when bony tenderness is found over the fifth metatarsal bone instead of the expected ankle joint area. Diagnosis of a Jones fracture is critical as the blood supply to that area of the bone is poor and can prevent proper healing. Radiographs of the foot are often sufficient to diagnose the Jones fracture. Treatment decisions are individualized; however, because of an increased chance of nonunion (lack of fracture healing) with nonoperative treatment, many athletes require surgical correction with screw fixation to ensure a good outcome.

Stress Fractures

Due to the frequent pounding from running and jumping, basketball athletes are prone to stress fractures of the lower extremity. To guide treatment, stress fractures are divided into high-risk or low-risk groups depending on the bones' available blood supply and subsequent healing potential. Common low-risk stress fracture locations include the metatarsal (main) bones of the feet and the medial (inside) tibial shaft of the lower leg. High-risk areas consist of the femoral (thighbone) neck, anterior (front) aspect of the tibia, tarsal navicular (small foot bone), and proximal shaft of the fifth metatarsal (outside foot bone). Radiographs can diagnose stress fractures after pain symptoms have been present for approximately 2 weeks; however, many go unnoticed on an X-ray. A bone scan or magnetic resonance imaging (MRI) is an excellent test to detect stress fractures not found on radiographs. Treatment predominantly includes rest from basketball, with a gradual return to the sport. With low-risk stress fractures, complete rest or simply a reduction in volume of play is appropriate. Most high-risk stress fractures, however, require an extended period of non–weight bearing with immobilization (cast) or consideration of surgery.

Medial Tibial Pain Syndrome (Shin Splints)

Media tibial pain syndrome (shin splints) is an exceedingly common diagnosis for those with shin pain. Shin splints and tibial stress fractures both cause pain on the inner tibia; however, the pain of shin splints is spread across a larger area. The diagnosis is made based on the history and physical examination. Imaging studies are used to exclude a stress fracture. Treatment is focused on rest, regaining of strength and flexibility, and adjustments of any of the athlete's biomechanical issues.

Upper Extremity Injuries

Shoulder Injuries

A variety of injuries can occur in the shoulder region. Direct impact to the shoulder can cause dislocations (at the shoulder joint) and separations (a ligament sprain on the top of the shoulder). Overuse injuries often cause irritation within the region of the rotator cuff. Acute and traumatic rotator cuff tears are rare, especially in the young athlete.

Wrist Injuries

An injury to the wrist often begins with a fall on an outstretched hand. Sprains of the wrist ligaments can occur with this mechanism. Initial treatment for sprains includes icing, elevation, and wrist bracing. When acute wrist injuries have persistent pain or swelling, X-rays are necessary to exclude a fracture. Breaking a fall by extending an outstretched hand can cause a fracture of the distal radius (the far end of the outside forearm bone) or the scaphoid (wrist bone). It is important that tenderness over the scaphoid bone and a potential fracture therein is not missed. The scaphoid bone tends to heal relatively poorly, and certain locations of this bone can be slow in healing. When a scaphoid fracture is displaced, surgical management is undertaken. For nondisplaced fractures, a period of nonoperative cast immobilization is attempted. Some physicians, however, advocate initial surgical management of nondisplaced fractures as this may result in a shorter healing time.

Finger Injuries

The "jammed" finger is one of the most common basketball injuries. It typically affects the proximal interphalangeal (PIP) joint (middle knuckle of the hand and fingers). When the basketball comes in direct contact with the tip of a straightened finger, a jammed finger frequently results, leading to pain and swelling at the PIP joint. Ice and buddy taping of the fingers are usually sufficient to treat this joint sprain.

A finger dislocation can happen with a similar mechanism as the jammed finger, though it is a much more urgent and serious injury. Reduction of the dislocated joint back to its normal state is required and commonly relieves pain. After any first-time dislocation, radiographs are necessary to evaluate for an associated fracture. Since soft tissue injury is common around the dislocated joint, swelling and loss of range of motion are seen. If the joint is stable and a significant fracture is not present, buddy taping is performed for 3 to 6 weeks along with early range of motion activities.

Spinal Injuries

The spinal column consists of three main areas: cervical (neck), thoracic (mid back), and lumbar (low back). Muscles surround these areas of the spine and provide stabilization and movement. With frequent jumping and landing, combined with twisting motions, a significant amount of strain is placed on the spinal muscles during basketball. Naturally, muscle strains of all areas of the back occur regularly. Relative rest, stretching, and ice are important initial treatment steps for strains of the neck and low back. Radiation of pain down the arms from a cervical injury or down the legs from a lumbar injury can indicate a more serious injury than a muscle strain. Further medical evaluation is appropriate in those cases.

Cardiac Events

A sudden cardiac event is the collapse of an athlete due to cardiac causes. Highly publicized incidents of collegiate and professional basketball players who have died from heart-related causes while competing have brought a great amount of attention to this topic. Despite this interest, sudden cardiac death remains an exceedingly rare event. A selective list of causes of sudden cardiac events includes hypertrophic cardiomyopathy (congenitally thickened heart wall), anomalous coronary artery (atypical path of the coronary arteries), and aortic stenosis (narrowing of the heart valve). Survival of those athletes who experience a sudden cardiac event has been shown to improve with the prompt use of automated external defibrillators (AEDs). These small, portable devices can be used by lay persons and are increasingly found in basketball gymnasiums, as well as other public places. Both athletes and spectators alike have benefited from the use of a nearby AED to quickly reverse a sudden cardiac event.

Concussion

Concussion is seen among basketball athletes after injuries such as striking the head on the floor or receiving a blow from an opponents' elbow to the head. Symptoms such as headache, nausea, dizziness, and imbalance are but a few of the common complaints of concussion. Memory, concentration, and orientation should be assessed. A graded return-to-play protocol is necessary as concussion features worsen with physical exertion. Those athletes who continue to have symptoms should be withheld from further competition until the symptoms have resolved.

Head and Facial Injuries

In a manner similar to concussion, many other traumatic injuries occur with contact from an elbow, finger, or basketball floor. Nasal, dental, eye, and skin injuries are seen on the basketball court. Nasal fractures most often require reduction based on cosmetic concerns. Two potential complications, difficulty breathing or a septal hematoma (collection of blood within the inner nasal wall), require urgent attention. Face masks are used to permit early return to play. Dental injuries may include loosened or even completely avulsed teeth. Mouthguards can prevent dental injury but are rarely mandatory at any level of basketball. The most common eye injury is abrasion of the cornea (surface layer of the eye). Skin lacerations occur most frequently at the face and more specifically on the chin, eyebrow, and lip. While local pressure and adhesive strips may be sufficient for minor and superficial wounds, sutures (stitches) are the definitive treatment for skin lacerations.

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See also Ankle Sprain; Anterior Cruciate Ligament Tear; Medial Tibial Stress Syndrome; Patellar Tendinitis; Stress Fractures; Sudden Cardiac Death

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Benefits of Exercise and Sports

The benefits of exercise and sports are much more than just gaining a nice physique. In our modern "connected" life, we tend to ride out our days stuck in one position. This inactivity leads to increased incidence of diabetes, heart disease, and premature death. A new branch of exercise physiology, inactivity physiology, inevitably emerged studying the increasingly chair-bound society. A study of 10,224 healthy men and 3,120 healthy women published in 1989 in the *Journal of American Medical Association* (*JAMA*) demonstrated a marked decrease in mortality with higher fitness levels. In addition to mortality, exercise helps us to have a higher quality of life. Insurance companies are recognizing exercise as a way to cut costs for seniors. Several major health insurance companies are offering free gym memberships to seniors. The program has reportedly cut sedentary behavior down by 70%. This senior population, known as masters athletes, has an improved quality of life and better health due to its dedication to exercising. Exercising is a major factor in delaying the aging process of the heart, lungs, and musculoskeletal system.

The NEAT Way to Increase Metabolism

A study of sedentariness at work demonstrated that people sit an average of 8 to 12 hours a day. The concerning part is that these same people sit for 7 to 9 hours on their leisure days, meaning they are more active when not at work but still are sedentary for the majority of the week. The sedentary lifestyle of work and play has been shown to decrease metabolism. The energy used in normal daily life is known as non–exercise activity thermogenesis, or NEAT. NEAT has recently been targeted as a key to decreasing weight and promoting a healthy lifestyle. NEAT is a factor that can be directly decreased by inactivity. In a study published in *Obesity Management* in 2006, James A. Levine and colleagues have shown that obesity is associated with a lower NEAT level, and obese individuals walk and stand two and a half times less than lean sedentary people. To target this, Levine et al. (2006) have used the approach of STRIPE: *S*elect a NEAT activity, *t*arget-define goals, *r*ewards identified, *i*dentify barriers and remove them, *p*lan a NEAT activity, and *e*valuate adherence and efficacy. Ways to increase a person's NEAT level in the office vary from walking to a coworker's desk instead of calling, climbing the stairs, using a balance ball as an office chair, and taking breaks to stand. A more extreme solution in the office place is to use "active" computer workstations, which consist of computers with stationary bikes and treadmills attached. At home, similar techniques can be applied: playing active video games, watching TV on a treadmill or bike, talking with friends during walks instead of on the phone, using push lawn mowers, and many other small changes can lead to increased NEAT level and weight loss.

Lean people walk 3.5 miles more than the obese in a study on nonexercise, normal-day walking. It makes sense that the obese walk less, but more important, with increased weight gain, walking decreases further. Clearly, this is a double-edged sword because with inactivity comes health concerns that make exercise more difficult to perform safely. However, as James Levine and Selene Yeager state in their 2009 book *Move a Little Lose a Lot*, with small increases in daily activity, the NEAT level, weight loss will ensue, stopping the downward spiral of weight gain and inactivity. The question can then be asked, Do lean people eat less, or is their energy expenditure more? To study this, a group of rats were bred selectively due to their resistance to obesity. The rats and controls were fed high-fat diets. The lean rats did not gain weight, which supported the theory that lean rats had a higher usage of energy. It was found that lean rats and people had a higher daily level of activity, which was measured as endurance capacity. To measure the endurance capacity, a sedentary group of people used a treadmill test to obtain their oxygen consumption, $\dot{V}O_2$max, which is correlated to endurance capacity. Not surprisingly, lean people had a higher $\dot{V}O_2$max, demonstrating that they are more active throughout a normal day; that is, they have a higher NEAT level. This entry is not suggesting that the only cause of obesity is daily activity or endurance capacity, but it is simply testing theories on why lean people despite similar caloric intake remain lean.

Inactivity and Health Problems

A new aspect of physiology has emerged to study this harmful trend of increasingly sedentary living—inactivity physiology. The basic principles of inactivity physiology are that sitting more and performing less nonexercise activity can cause a decrease in fitness and an increase in mortality. Also, the body's response to inactivity varies greatly in comparison with the body's cellular/molecular response to exercise. Furthermore, the response to exercise in an inactive person would differ from the response in a person who had a more active baseline. A few epidemiologic studies have been done demonstrating that inactivity leads to increased risk for cardiovascular disease and death. The British professor Jeremy Noah Morris in the 1950s made the observation that deaths from heart disease were more common in people with sedentary jobs. He then studied a few groups of people to determine if this hypothesis was true. First, he studied the conductors and drivers of London's double-decker buses. He found that the active conductors of the double-decker buses had a lower incidence of coronary heart disease (CHD) than did the sedentary drivers. Then he was able to reproduce this study in active postmen versus sedentary telephonists and other government desk workers. The physique of a conductor was overall leaner and the waist band size smaller than the drivers'. This abdominal obesity became known as central obesity. After accounting for weight, age, and height, the rate of sudden death from coronary artery disease (CAD) was two times higher in the drivers, even if they had a "slim" physique. As expected, the conductors had lower low-density lipoprotein (LDL) cholesterol and triglyceride levels. Further studies of fitness level and heart disease demonstrated that regardless of body mass index (BMI), low fitness levels led to increased risk of CHD and mortality; the authors even stated that a low fitness level was comparable with diabetes as a health morbidity contributor.

In addition to increased cardiovascular morbidity, inactivity has been shown to be detrimental to other areas of health as well. A high level of exercise in postmenopausal women has been shown to decrease breast cancer risks. Maintaining a waist circumference below 102 centimeters and moderate-intensity physical activity are associated with sustaining proper erectile function. Asthma has been shown to decrease physical activity in adults; this population is characterized by a higher number of emergency room visits, greater use of medication/inhalers, sleep issues, and inability to go to work. Interestingly, a prospective study showed that asymptomatic children with low physical fitness had increased development of asthma in adolescence.

It was speculated that inactivity led to an increase in systemic inflammation. Another study demonstrated that tumor necrosis factor alpha and C-reactive protein, inflammatory reactants, increased with inactivity. This systemic inflammatory state is hypothesized to increase the risk for tumor growth, insulin resistance, and CHD. Thus, exercise acts as an anti-inflammatory agent; skeletal muscles release various myokines that have endocrine and paracrine effects on visceral fat and fat oxidation signaling. A molecular study by Marc Hamilton demonstrated that decreasing the daily low-level activity led to a change in the cellular regulation of skeletal muscle lipoprotein lipase, a protein that is important in triglyceride catabolism and for high-density lipoprotein (HDL) cholesterol. Inactivity in essence decreases muscle lipoprotein lipase, decreases HDL concentration, and decreases triglyceride uptake. In this study, when sedentary people added vigorous exercise to their daily routine, it did not have as much effect on the skeletal muscle lipoprotein lipase as did increasing baseline activity. In another study by Hamilton, treadmill walking was shown to raise lipoprotein lipase eight-fold within 4 hours after inactivity. This perhaps is why even low-level exercise, such as walking, is beneficial in preventing heart disease.

Exercise in Seniors

Athletes over 40 years of age, known as *masters athletes*, have been shown to have improved life expectancy, higher life satisfaction, and improved overall health. A survey conducted by the Arthritis Foundation showed that 64% of masters athletes reported feeling an average of 11 years younger than their actual age, while 40% reported having a healthier and more physically fit lifestyle than in their 20s. It is interesting to note the latter fact, that these incredibly active people are more fit as seniors. Moreover, 33% of them boasted that they can beat their children in at least one sport. These people are not the exception but the standard. All individuals have the chance to maintain this high quality of life and functional capacity throughout their life span if they choose to avoid a sedentary lifestyle. The sedentary lifestyle is quite detrimental to aging; it has been shown that the health of sedentary people declines twice as fast as that of their age-matched active counterparts.

Contrary to popular belief that older individuals cannot exercise or remain active due to age, this has not been shown to be true. In a study of track athletes aged 50 to 85 who participated in the 2001 National Summer Senior Games, running times across all distances declined with age. While this trend was expected, the surprising finding was the small degree of performance decline that occurred with age. Until the age of 75, the observed decline was slow and linear, with decreases of less than 2% per year. This decline was not found to be statistically significant. At age 75, however, the rate of decline jumped to approximately 8%. This trend of performance decline with age is shown in Senior Olympians running the 100-meter dash. These results suggest that if disuse and disease are eliminated, individuals should be able to maintain high levels of functional independence until the age of 75. Therefore, the loss of independence before the age of 75 must be attributed to disuse, destructive lifestyle habits, disease, or genetic predisposition. Although it has been shown in multiple studies that at age 75 the aging process becomes a factor in exercise, this still does not stop the Senior Olympians from participating in sports activity. It is not uncommon for competitors to run into their 90s and, more impressively, gain a position on the medal stand.

Health Benefits From Exercise

These masters athletes are quite serious about fitness, although they cannot ward off some aspects of aging with exercise. The good news is that even if aging is inevitable, intense exercise has been shown to slow its process.

Lungs

With age, the efficiency of oxygen delivery decreases, which affects peak performance. Oxygen is a much more efficient energy producer than any other catabolic pathway. This change in performance with aging is attributed to a lower lactate threshold, lower exercise efficiency, and lower $\dot{V}O_2max$. The $\dot{V}O_2max$ is the most important factor, and a reduction in $\dot{V}O_2max$ is the primary reason for a decline in functional endurance with aging. The $\dot{V}O_2max$ decreases 5% to 15% per decade after age 50; this decline is mainly due to changes in cardiac output. An intense endurance workout program can cut this decline of $\dot{V}O_2max$ in half.

The lung tissue also changes with age and body abuse. The lungs become stiffer and cannot expand to hold the amount of air that a more elastic lung can hold. This capacity decreases by 250 milliliters per decade. Also, from age 20 to 70, the maximum breathing capacity declines by 40%. Smoking and asthma can also lead to decrease in the elasticity of the lungs. There is also a decline in the number of lung capillaries, which further decreases oxygen exchange. With the combination of less elasticity and decreased capillaries, the lungs do not exchange oxygen for carbon dioxide in the blood as efficiently. The only way to decrease the damage to the lungs is to stop smoking.

Heart

The heart cannot take a moment's rest in the 80+ years of life; it beats on average 80 times per minute and over 50 years this is 2.1 billion heartbeats. With all that daily work, it is not surprising that the heart ages. The maximum heart rate, heart muscle contractility, and stroke volume all decline with age. Without an aerobic workout program that stresses the heart, the muscle, just like a biceps or quadriceps, can weaken. Other control measures to keep the heart pumping strongly include controlling the blood pressure, reducing emotional stress, and, as always, eating a well-balanced diet. The numbers can be frightening, with 40% of deaths in people aged 65 to 74 resulting from heart disease, which increases to a staggering 60% in people above 80. The cardiac output is only twice the resting capacity in an 80-year-old, while a 20-year-old has 3.4 to 4 times the resting capacity. To increase cardiac output, the heart pumps harder; in an older person, this is a challenge as well because with age the arteries become less elastic and therefore the blood pressure increases. To counteract the higher blood pressure, the left ventricle becomes hypertrophied. This leads to a heart that can be up to 40% larger than in a young person. The heart rate maximum decreases 1 beat/year after age 10, and the heart is not capable of beating as quickly due to the aforementioned reasons. The good news is that the effects of the aging process on the heart can be delayed with an intense endurance workout program. This strengthens the heart, causing the resting heart rate to be lower because the heart muscle is more efficient. The muscle can make more forceful contractions to squeeze out the blood and therefore does not need to squeeze as often.

In addition to the arteries becoming less elastic, they may also harden due to buildup of cholesterol and calcium deposits. High-fat diets and smoking can exacerbate this. The repeated theme of exercise and a well-balanced diet can prevent narrowing of the arteries and help control blood pressure.

Skeletal Muscle

Age-related changes affect a muscle's overall power and strength. The changes seen are due to sarcopenia, the loss of lean muscle mass. This decreases the size of muscle fibers, leads to the loss of muscle cells, and decreases muscle flexibility. Lean muscle mass starts to decrease at age 25 with the loss of muscle fibers and loss of fiber size, mostly fast twitch muscle. By age 80, 50% of lean muscle mass is lost. This dramatically increases with a sedentary lifestyle. More important, with inactivity the muscle becomes replaced with fat. However, an intense endurance workout program can again prevent age-related changes. In a Swedish and Finnish study, the vastus lateralis of 18- to 84-year-old male sprinters was studied, and the researchers found the typical age-related reduction in the size of fast twitch fibers, but these fibers were preserved at a high level in the older runners.

Old muscle has the ability to hypertrophy, just like young muscle, if the muscle is exercised. Multiple studies have shown that high-intensity strength training results in substantial, continual increases in strength. This has been shown true for deconditioned elderly individuals as well. The strength training has been shown to be essential in keeping muscles healthy. A study of masters athletes who mainly take part in aerobic exercise for fitness found muscle composition similar to that of age-matched sedentary controls. However, masters athletes who had workout routines that included weight training had muscle composition similar to controls who were 40 years younger. Other research has shown that regardless of age, if people are using comparable training regimens, it results in similar muscle composition. In essence, the aging process can go seemingly unnoticed with an intense and consistent strength training program.

Bone

The loss of bone with aging is a big concern since it leads to many complications. Bone mineral density decreases with age, but risk factors such as inactivity, smoking, low calcium intake, and low sunlight exposure or vitamin D intake can accelerate bone loss. A decrease in bone mineral density leads to osteoporosis. These soft bones are much more prone to fracture than normal-density bone. A seemingly harmless fall in an osteoporotic person can lead to a complex fracture and quite possibly permanent disability. A once independent elderly person may then end up in a nursing home. Bone loss is inevitable, but osteoporosis is not. After the age of 40, bone is lost at 1.5% to 2% per year, and women lose bone twice as fast as men. The key to bone health is, of course, eating a well-balanced diet rich in calcium and vitamin D but also performing weight-bearing exercises. For example, although swimming is an excellent cardiovascular activity, it does not stress the bones. Bones need a stress or load to maintain density. A study performed at the University of Pittsburgh on bone density in senior athletes found that the women had normal bones, even the Senior Olympians in their 80s. The prevalence of osteoporosis was lower than in the general population at any age.

New Trends in Exercise

Circuit Training

Circuit training has become increasingly popular. Many health clubs have circuit training workout classes or preprinted circuit workouts for members to use. One successful chain of women-only health clubs, Curves, is devoted entirely to circuit training. The workouts are for only 30 minutes, and they combine strength training with aerobic activity.

Dance Exercise

At every health club, there are multiple workout classes that include dance workouts. The themes range from African dance, to flash dance, to Zumba, an increasingly popular style that originated in Colombia. The dance numbers are salsa, meringue, samba, reggaeton, and other Latin rhythms. The class consists of slow- and fast-tempo songs for a strength-training and cardiovascular workout. Moving to the fast beat of the music, the aerobic expenditure can be intense.

Exercise Video Games?

Exercise has even become a trendy subject in the video game world with the advent of interactive video games. One of these gaming systems is the Wii by Nintendo. The Wii holds 48.8% of the world market, and Wii Fit is listed among the top three video games in the past few years. This gaming system requires standing and movement for game play, in contrast to typical video games where people are seated and stationary. The Wii Fit, in particular, has an exercise program that incorporates aerobics, balance, and strength training. In both adults and children, the Nintendo Wii has been scientifically shown to increase energy expenditure. Although traditional exercise such as walking is always beneficial and free, the Nintendo Wii may be an attractive alternative to motivate previously sedentary people.

While our society has become increasingly sedentary, our bodies still need exercise and activity every day. The entire body depends on exercise to keep working efficiently. The lungs, heart, muscles, and bones all benefit from exercise, which can be anything from jogging to taking the stairs at work, push mowing the lawn, or boxing a friend on a video game. Although any extra movement a day can mean pounds lost or a lower resting heart rate, only intense exercise can elevate a person to the level of the masters athlete. These older people have taken the aging process head on and are winning, with better health, longer life, and more satisfaction.

Mollie Manley and Vonda J. Wright

See also Cardiovascular and Respiratory Anatomy and Physiology: Responses to Exercise; Exercise and Disease Prevention; Exercise Prescription; Gender and Age Differences in Response to Training; Sport and Exercise Psychology

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Beta Agonists

Beta agonists are medications commonly used to treat "reactive airway disease," or *asthma*. These medications stimulate the beta-2 receptors, which are found in the lungs in very small airways called alveoli. The beta-2 receptors are present in the muscles that surround the alveoli. When these muscles contract, the alveoli constrict, and less air moves through. This process is called *bronchoconstriction*. These alveoli have very small cross-sectional space so that even a mild constriction can significantly alter the airflow. This is what happens in an asthma exacerbation. The beta agonists relax the muscles that surround the alveoli.

In asthma, there are often triggers that cause bronchoconstriction. Common triggers are exposure to cold, stress, exercise, or allergens such as animal dander, pollen, medications, or food. It is important for anyone with asthma to learn his or her specific triggers and avoid them. Bronchoconstriction can be rapid and deadly, and sometimes beta-agonist treatment is not enough to reverse it. Asthma has an inflammatory component as well, which means that the alveoli swell and mucus is produced. Beta agonists cannot treat this aspect of asthma, and the inflammation will get worse if the asthma is left untreated or if there are repetitive exposures to triggers. In addition, continued use of beta agonists may make them less effective over time.

Any chemicals that stimulate beta receptors are considered beta agonists. Most of the medications that are designed to stimulate beta-2 receptors will also stimulate beta-1 receptors, which are found in the heart and control the heart rate. That is why beta-agonist medications usually increase the heart rate (i.e., stimulation of beta-1 receptors in the heart as an unintended consequence). Epinephrine (adrenaline), caffeine, and cocaine are some examples of beta agonists. Cold medications such as pseudo-ephedrine and some herbal supplements (such as *ma huang*) have beta-agonist properties. One of the most commonly used beta agonists in the treatment of asthma is albuterol. Albuterol is most often inhaled through a metered dose inhaler (MDI, or "puffer"). It is also available in pill form or inhaled in powder form.

Athletes use beta agonists to prevent or treat reactive airway disease. They are sometimes abused to increase the heart rate and get a competitive advantage. Beta agonists were previously thought to have mild anabolic (muscle building) properties, and so their use in competition was strictly prohibited. After further study, there does not appear to be any significant anabolic effect. This fact, and the significant rise of asthma rates worldwide, has contributed to relaxing of the restrictions on beta-agonist use in competition. Certain beta agonists such as formoterol, salbutamol, salmeterol, and terbutaline are permitted but regulated in international competition and during training. These medications are permitted to be taken by inhalation to prevent and/or treat asthma and exercise-related respiratory problems. Athletes still need documented proof that they have reactive airway disease and a prescription in order to compete while taking these medications (therapeutic use exemption).

Beta agonists have a role in treating asthma, but they must be used properly, and an athlete needs to be aware of the risks and side effects. Common side effects include jitteriness, increased heart rate, tremor, and difficulty sleeping. Beta agonists can exacerbate or cause arrhythmias (erratic and sometimes deadly irregular heartbeats).

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See also Asthma; Beta Blockers; Physiological Effects of Exercise on the Cardiopulmonary System

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Beta Blockers

Beta blockers are a group of medications that are typically used to treat hypertension and heart disease but have also occasionally been abused by athletes to gain a competitive advantage. If a medication name ends in "-lol," such as atenolol or carvedilol, it is usually an indication that the medication is in the beta blocker family.

Beta blockers are antagonists (blockers) to beta-1 (and to a lesser degree beta-2) receptors. Stimulation of beta-1 receptors increases the heart rate, and therefore, taking beta blockers will slow the heart rate. In the body, chemicals such as epinephrine (adrenaline) will increase the heart rate in response to fear or excitement or with activity such as exercise by stimulating beta-1 receptors in the heart. Beta blockers are typically used to treat high blood pressure or irregular heartbeats. They have been used for a long time and have saved many lives, especially after someone has had a heart attack.

Beta blockers can also minimize tremors. For this reason, people have used them to control symptoms of stage fright or before public speaking. This is also one of the reasons why they are banned in certain types of athletic competition, such as biathlons. Biathletes have to run or ski to certain checkpoints. They then must shoot targets, sometimes with an air rifle or pistol or with archery. Beta blockers give an advantage by controlling the heart rate and tremors, making it easier to take a steady shot after running or skiing. Athletes who do artistic performances, such as ice skaters, gymnasts, or dancers, may be tempted to use beta blockers to minimize the physical signs of stress and to project confidence.

Common side effects of beta blocker use include dizziness, fatigue, or syncope (passing out). They are especially dangerous in athletes who use them for performance enhancement rather than to treat a medical condition. Exercise increases the need for oxygen, and the heart beats faster to get oxygenated blood to the tissues that need it. If the heart rate is artificially limited, dangerous drops in blood pressure can occur. In addition, beta blockers can induce arrhythmias (erratic and sometimes deadly heart rhythms). Nonselective beta blockers may also induce asthma symptoms since there is a beta receptor in the lung (beta-2 receptor) that needs to be stimulated to keep the airways open. Blocking these receptors causes the tiny muscles around the airway to constrict.

Michael O'Brien

See also Beta Agonists; Hypertension (High Blood Pressure)

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Biceps Tendinitis

Biceps tendinitis is an injury to tendon of the long head of the biceps in the upper arm and shoulder. Although the term *tendinitis* implies acute inflammation, this disorder is usually degenerative in nature, and acute inflammation is relatively rare; thus the term *tendinopathy* is increasingly preferred. Most biceps tendinitis can be thought of as a fraying and irritation of the ropelike biceps tendon as it courses from the anterior or front of the shoulder to deep within the shoulder joint. It is most commonly seen in overhead athletes such as swimmers and tennis players or middle-age patients who do repetitive lifting, pushing, or pulling. Unfortunately, definitive treatment options are limited. Management focuses on symptom relief and physical therapy to correct general shoulder dysfunction.

Anatomy

The shoulder joint consists of the shallow ball-and-socket articulation of the humerus (upper arm bone) and scapula (shoulder blade). In this way, the humerus sits on the scapula like a golf ball on a tee. The scapula moves freely on the posterior chest wall and is connected to the rest of the skeleton only by the clavicle, or collarbone. These relationships allow the shoulder to have tremendous mobility but put a greater strain on the soft tissue structures (muscles, ligaments, and tendons) to maintain stability and function.

One of these soft tissue structures is the tendon of the long head of the biceps, which begins within the shoulder at a bony prominence located at the superior (top) of the glenoid (socket part of the scapula). Here at its origin, the tendon is confluent with glenoid labrum (cartilage rim that deepens the shoulder socket). From the glenoid labrum, it extends as a ropelike structure that courses along the head (ball) of the humerus, exiting the shoulder through a groove in the humerus, where it is held in place by a roof of thick connective tissue. Once outside the shoulder joint, it continues down the arm for several centimeters before it blends into the biceps muscle.

Causes

The exact cause of biceps tendinitis remains controversial. Although tendinitis implies that there is a primary inflammatory cause for this disorder, acute inflammation is not common and likely represents a small subgroup of patients with biceps tendinitis. More commonly, this diagnosis is seen in the setting of biceps tendon degenerative changes. Degenerative changes in the tendon are due to wear and tear from overuse, age, or impingement from the bony structures of the shoulder. These degenerative changes in the tendon are marked by a tendon that is softened, thickened, and frayed. Fluid, debris, and calcification can be seen around the tendon. Occasionally, the biceps tendon can be unstable in the groove of the humerus, moving up and out of its normal position, a condition called *subluxation*.

These degenerative changes in the biceps tendon are often seen alongside other shoulder problems, including rotator cuff tendinitis or tears, shoulder impingement, bursitis, and shoulder instability, suggesting that biceps tendinitis is the result of a more general shoulder dysfunction. This also provides the rationale for treating biceps tendinitis through general shoulder rehabilitation (Figure 1, next page).

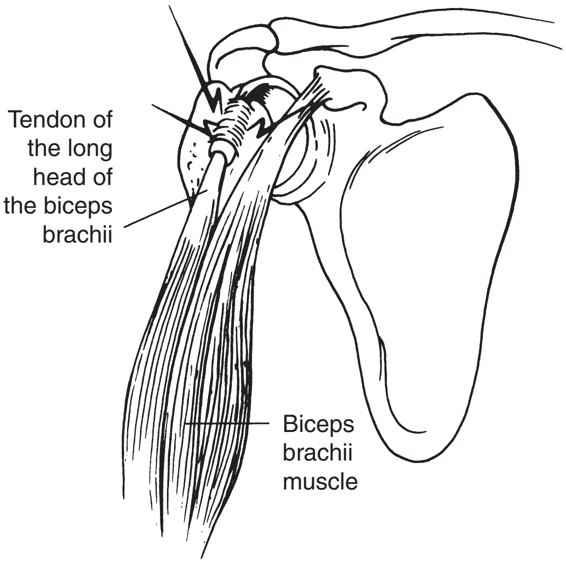

Figure 1 Biceps Tendinitis

Note: The tendon of the long head of the biceps is especially vulnerable to irritation because it passes through a narrow groove in the ball of the humerus.

Symptoms

Patients with biceps tendinitis have pain over the anterior shoulder that can radiate slightly down the arm. They may report a painful clicking or popping sensation in the anterior shoulder. Symptoms are aggravated by reaching, overhead activities, or push/pull movements. Pain may be present at rest and may worsen at night. Patients may report point tenderness over the biceps tendon. Although some patients report a particular event or injury, most cases of biceps tendinitis have an insidious onset.

Diagnosis

There is significant overlap of the symptoms and exam findings of biceps tendinitis and other common shoulder conditions. Moreover, as mentioned above, these conditions commonly coexist in the patient presenting with shoulder pain. Therefore, it is important to consider and evaluate the patient for associated shoulder pathology when symptoms suggest biceps tendinitis. Several clinical tests are used for the diagnosis of biceps tendinitis. These include palpation of the biceps tendon, the Speed test, and the Yergason test.

The biceps tendon should be palpated in both shoulders. Asymmetrical tenderness in the symptomatic shoulder has long been regarded as the hallmark of diagnosis. Palpation of the tendon takes some practice and may be difficult in a heavily muscled or obese patient. Internal and external rotation of the shoulder can help in identification of the biceps tendon and may suggest a subluxating tendon if the tendon can be felt to pop out of the groove. Flexion (bending) and extension (straightening) of the elbow during palpation may reveal crepitus (a tactile creaking).

The Speed test is preformed by having the patient extend the elbow with the palm facing up. The arm should be elevated so that it is slightly less than parallel to the floor. In this position, the patient is asked to resist a downward force applied by the examiner. Pain is considered a positive test. Studies suggest that this test is moderately sensitive for biceps tendinitis but is not specific for the condition. This means that a negative test makes it less likely that the patient has biceps tendinitis but a positive test does not provide much help in determining if a patient has biceps tendinitis.

The Yergason test is conducted by having the patient flex the elbow and rotate the hand from a palm-down position to a palm-up one while the examiner resists the motion. Reproducing pain at the location of the biceps tendon is considered a positive test. Studies on the accuracy of the Yergason test in diagnosing biceps tendinitis suggest that it is reasonably specific but insensitive. Therefore, when positive, the Yergason test helps in confirming the diagnosis of biceps tendinitis, but when negative, it does not exclude the disorder.

X-rays can be used to assess the bony architecture of the shoulder and may provide helpful information to your physician but does not yield a specific diagnosis of biceps tendinitis. Magnetic resonance imaging (MRI) can be used to evaluate the biceps tendon, but MRI is usually reserved for cases of suspected significant rotator cuff or labral pathology. Although not widely available in the United States, musculoskeletal ultrasound is a good choice for evaluating the biceps tendon. It allows for a detailed assessment of the tendon and its surrounding structures while allowing the physician to evaluate the dynamic function of the biceps tendon in the bicipital groove of the humerus.

Treatment

Nonsurgical Treatment

Initial treatment for biceps tendinitis focuses on symptom management and avoidance of aggravating activities. Patients should be temporarily restricted from repetitive or heavy overhead lifting, pushing, pulling, or throwing. A 2-week trial of scheduled nonsteroidal anti-inflammatory drugs (NSAIDs), such as ibuprofen or naproxen, is reasonable. Application of ice to the anterior shoulder for 20 minutes/hour, repeated as needed, is helpful for acute exacerbations of symptoms. The patient should not immobilize the shoulder; rather, frequent home rehabilitation exercises should be preformed as soon as tolerated. These can be as simple as repetitive pendulum circles or tracing the alphabet with the hand with the arm hanging straight down. The patient should also begin to slowly walk the hand up a wall to an overhead position; he or she can move closer to the wall if the pain is within tolerable limits. For recalcitrant or severe cases, steroid injections into the biceps tendon sheath or shoulder joint may be administered.

Following resolution of acute symptoms, general shoulder rehabilitation based on a home exercise program or under the guidance of a physical therapist may be prescribed. This will focus on exercises designed to strengthen and improve shoulder positioning in order to maximize function.

Surgical Treatment

Surgery is rarely preformed in patients with biceps tendinitis. Patients with chronic biceps tendon pain that has not responded to aggressive conservative care are sometimes referred for surgery. During surgery, attempts are made to correct the associated shoulder pathology, and the biceps tendon is sometimes cut; this procedure is called *tenodesis*.

J. Bryan Dixon

See also Rotator Cuff Tears, Partial; Shoulder Impingement Syndrome

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Biceps Tendon Rupture

The biceps muscle is an integral component of the upper extremity. Injury to the proximal tendon is relatively common in older people and can often be associated with other shoulder pathologies. Injury to its distal tendon is an uncommon injury; nonetheless, it can produce significant functional disability. Many surgical and nonsurgical treatment options exist for these injuries.

Anatomy

Proximally, or at the shoulder, the biceps muscle has two heads, from which its name is derived. The muscle connects to the bone through its tendon, thereby allowing the body part to move with the contraction of the muscle. The shorter head of the biceps connects to the bony prominence of the scapula, called the *coracoid*. The longer head connects to the top of another part of the scapula called the *glenoid*. The glenoid is the "socket" with which the humeral head articulates, although its shape is closer to a saucer than to a socket. A portion of the biceps tendon travels within the shoulder joint and can easily be visualized during shoulder arthroscopy. The function of the proximal two heads is two-fold. The first is to help flex the shoulder joint, or bring the arm straight out in front of the body. The second is to help keep the humeral head located in the glenoid during movement of the shoulder joint.

Distally, or at the elbow, the biceps muscle forms a single strong tendon. This tendon crosses the elbow joint and thereby imparts two movements: (1) bending of the elbow (flexion) and (2) rotation of the forearm into the palm-up position (supination).

The biceps can be injured at any of these three tendons, as well as at the middle of the muscle belly. Injuries to the muscle belly or to the short head of the biceps tendon are very rare injuries and are not discussed further. The most common injury occurs to the tendon of the long head of the biceps at the shoulder, and the next common injury is to the distal biceps tendon at the elbow.

Causes

Rupture of both types of biceps tendons most commonly occurs from chronic, repetitive injury. This causes degeneration within the tendon, leading to decreased tendon strength. Impaired blood supply to the area of the tendon also contributes to degeneration as this impairs tendon healing. Eventually, a force occurs that exceeds the strength of this weakened tendon and leads to tendon rupture. Injury to the tendon from sharp, penetrating trauma is rarer.

The biceps tendon at the shoulder is intimately associated with other shoulder anatomic structures: the rotator cuff (a group of muscles that surround and control shoulder movement and stability) and the glenoid labrum (a cartilage within the shoulder joint). Repeated and chronic injury to these other structures can irritate and injure the proximal biceps tendon. Rotator cuff impingement, rotator cuff tear, and superior labral tear are commonly associated with proximal biceps injury (see Figure 1).

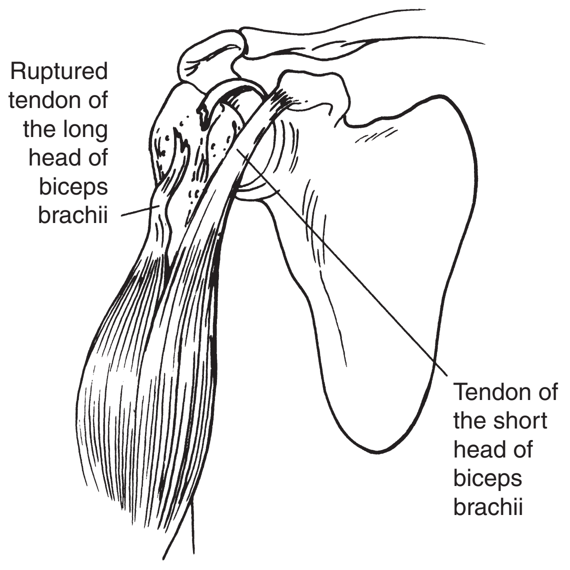

Figure 1 Rupture of the Long Head Tendon of the Biceps

Epidemiology

Injury to the proximal biceps tendon is common in older people, in whom concomitant shoulder pathology is also present. In the athletic population, it is most common in overhead throwing athletes.

Distal tendon injuries occur almost exclusively in men aged 40 to 60 years. Injury occurs typically when a sudden force is applied to a partially bent elbow. Contraction of the biceps occurs to decelerate the arm, and this causes failure of the weakened tendon.

Symptoms

Pathology of the proximal biceps tendon typically presents with pain. The pain is usually located over the tendon in the front of the shoulder. If the injury coexists with other shoulder pathologies, the pain can be located almost anywhere. Any movement that puts strain on the inflamed tendon will aggravate the symptoms. Likewise, tests for rotator cuff and labral injury will be painful, although not always localized to the tendon. Not too uncommonly, a patient will describe a long history of symptoms followed by a "pop" felt in the shoulder. The pain will usually improve after this presumed rupture of the tendon. Bulging of the biceps muscle, also known as the "Popeye muscle," will occur after complete rupture. If the tendon is unstable within its path, often the complaint will be clicking or snapping felt within the shoulder with movement.

Distal biceps rupture is usually dramatic. The history will reveal a story similar to that described above, in which the biceps contracts against a sudden weight. Pain in the front of the elbow is reported and can often be accompanied by bruising or discoloration. A "Popeye muscle" can also be observed. Sometimes people will present weeks after the injury has occurred and will complain of weakness while bending the elbow and while turning the forearm palm up, as when using a screwdriver to drive in a screw.

Diagnosis

Because examination of the shoulder reveals many overlapping symptoms and concomitant pathologies, it can sometimes be difficult to make the diagnosis of biceps tendon injury on history and physical exam. Plain radiographs are typically normal or may suggest some level of impingement syndrome. The study of choice for suspected tendon injury is magnetic resonance imaging (MRI). This has the added advantage of being able to assess the entire shoulder joint for other pathologies. The addition of contrast material into the shoulder joint greatly enhances its diagnostic ability.

Unlike the proximal tendon, complete rupture of the distal biceps tendon can most often be diagnosed by the history and physical exam. MRI can be helpful in the context of partial tears or nontypical presentations.

Treatment

Nonsurgical Treatment

The first line of treatment for proximal tendon derangements is nonoperative. The usual combination of rest, ice, and anti-inflammatory medications can improve symptoms. Physical therapy and occasional corticosteroid injection can be used in specific cases. Most cases will respond well to these modalities. When conservative measures fail, surgery should be considered.

Complete distal tendon injury is usually treated with surgical repair. Partial tears can usually be managed nonoperatively. This modality uses rest, ice, and anti-inflammatory medications to manage local pain symptoms. Continued treatment with physical therapy is aimed at regaining elbow motion as well as muscle strength. Complete tears managed conservatively will result in residual muscle weakness while bending the elbow (flexion) and turning the forearm palm up (supination), as well as early muscle fatigue. Cases that fail nonoperative treatment should be considered for surgery.

Surgical Treatment

Various surgical treatments exist for the treatment of proximal biceps injury. Often the biceps is addressed at the same time as other shoulder pathologies, such as those of the rotator cuff or labrum. For small partial tears, the tendon can be simply debrided—the rough, degenerative portion removed to allow healing of the remaining tissue. For cases where much of the tendon is involved, simple release of the tendon from the glenoid will usually relieve symptoms, although typically some weakness and cosmetic change can occur. In the athletic population, or anyone in whom weakness would be undesirable, significant degeneration of the tendon is treated by releasing the damaged portion and then anchoring the remaining part to the humerus. This is called tenodesis.

Some controversy currently exists regarding the optimal treatment for biceps pathology. The surgeon must tailor treatment to each individual patient, taking into consideration all factors, including the dominant extremity, occupation, age, and other shoulder pathology.

Postoperative physical therapy is necessary following any type of surgical treatment. The goals of therapy are to decrease local symptoms from surgery, regain shoulder motion, and enhance strength. In cases where the biceps tendon is repaired or tenodesed, time must be allowed for healing before significant stresses are put through the tendon.

The treatment of complete distal biceps rupture is usually surgical. While nonoperative treatment is always an option, and is recommended for partial tears, most active patients are unwilling to accept muscle weakness and mild cosmetic deformity. Acute (recent) tears are easier to repair than chronic (old) ones. If much time has passed since the rupture, the muscle retracts, and it becomes difficult to repair directly. In these cases, complicated reconstructions are necessary. Acute tears can be repaired through several different techniques. Drill holes, suture anchors, and EndoButton (Smith & Nephew Endoscopy, Andover, Massachusetts) fixation have all been successfully used to repair the torn distal biceps tendon to the radius through a variety of surgical exposures.

Postoperative physical therapy is required for elbow, wrist, and hand range of motion. Once the tendon is allowed to heal, strengthening of the entire upper extremity can promote faster return to activity.

Complications

Various complications can occur in the treatment of biceps tendon injuries. Nonsurgical treatment can result in continued pain and disability. Surgical treatment can result in shoulder stiffness and pain, failure of the tendon to heal to the humerus (tenodesis), or cosmetic deformity (Popeye muscle).

Nonsurgical treatment of distal biceps rupture can result in the loss of elbow motion or weakness. Surgical complications of distal biceps repair include injury to the sensory or motor nerves around the elbow, rerupture of the tendon, and elbow stiffness from postoperative calcium formation around the elbow (heterotopic ossification).

Loren M. Geller

See also Rotator Cuff Tears, Partial; Shoulder Arthritis; Shoulder Impingement Syndrome; Superior Labrum From Anterior to Posterior (SLAP) Lesions; Tendinitis, Tendinosis

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Biking, Injuries in

Cycling injuries occur as a result of riding a bicycle. This entry will focus on the most common causes of cycling-related injuries, along with some treatment options and recommendations to eliminate pain. The role of bike fit, the changing of a bicycle's positioning to accommodate the rider's posture, will be addressed when appropriate. Pain is the primary restriction to enjoyment of bicycling, and the prevention and rehabilitation of injuries causing pain are important aspects of sports medicine.

Road Rash

"Road rash," or *abrasion*, occurs when skin comes in contact with the pavement. The resultant skin damage is similar to a sunburn or heat burn and is classified as first, second, or third degree depending on the severity.

Treatment

First aid involves cleaning or scrubbing the skin with soap and water. If you are able to clean the area enough to remove any signs of dirt or gravel, then using polysporin antibiotic ointment two to three times daily, with a bandage, is ideal. The goal for healing is to keep the area moist and prevent any scab formation. As with sunburn, using sunscreen to prevent further damage is important. If you are unable to clean the wound adequately or control bleeding or if the pain indicates more than a simple sunburn, then visit a medical professional.

Head Injuries

Head injuries are the most common cause of death and serious injury in cycling, and this risk is decreased greatly by wearing an appropriate helmet. The Insurance Institute for Highway Safety reported that 95% of bicyclists killed in 2006 were not wearing helmets.

Treatment

When a head injury is suspected, do not take aspirin or nonsteroidal anti-inflammatory drugs (NSAIDs; such as ibuprofen) unless directed by a physician. Immediate medical attention should be sought if an injury results in loss of consciousness or memory. Medical attention should also be sought if confusion, dizziness, slurred speech, nausea or vomiting, disorientation, extreme sleepiness, pupil dilation, loss of balance, vision or hearing problems, changes in taste or smell, or other signs develop.

Clavicle Fracture

Any bone can break in a crash, but the most common fracture is of the clavicle (or collarbone). The clavicle is the S-shaped bone that runs from the front of the shoulder to the sternum, and it is usually fractured when a cyclist falls onto an outstretched arm while trying to break a fall.

The risk of a serious or deadly head injury is decreased greatly by wearing an appropriate helmet.

Source: John Rasmussen/iStockphoto.

Treatment

Most collarbone fractures will have significant healing in approximately 6 weeks. Whereas treatment is based on the severity of the fracture (which usually requires almost no treatment), medical attention is recommended at the time of injury. Riding a stationary bicycle is allowed immediately, with outdoor riding often permitted by 6 weeks.

Anterior Knee Pain

Anterior knee pain is often called *chondromalacia patella* and is the most common area of chronic pain in cyclists. There are many possible causes for these symptoms, including the following:

- *Posture:* being “knock-kneed,” “bowlegged,” or having a leg length difference
- *Improper bike fit:* a saddle positioned too far forward or too low, cranks too long for one’s anatomy, or a toe-in or toe-out position of the cleats
- *Use of excessively large gears*
- *Muscle imbalance or inflexibility*

Treatment

First aid involves the RICE (*r*est, *i*ce, *c*ompression, *e*levation) method and acetaminophen for pain relief. Bike-fit strategies include these potential adjustments:

- Raising and/or moving the saddle back decreases knee angle at maximal load.
- Shorter cranks decrease leverage and often result in higher cadence and less resultant force on the knee.
- Adjusting cleat position to minimize sideways force, using arch-supporting orthotics for hyperpronation, and/or shims under the cleat to address any leg length differences ensures proper force distribution.

Rehabilitation exercises consist of hamstring stretches and target strengthening of the medial quadriceps. On-the-bike strategies include standing more during uphill riding, using smaller gearing to increase cadence, and riding on flatter terrain. If pain does not resolve or worsens, visiting a medical professional is recommended.

Tendinitis

Tendinitis is defined as inflammation of a tendon. The areas most susceptible to this are the patella or quadriceps tendon (front of the knee), the hamstrings (back of the knee), the pes anserine group (medial knee), the iliotibial band (ITB; lateral knee), the tibialis anterior (front of shin), and the Achilles tendon (back of the calf).

Common causes for tendinitis include the following:

- *Improper bike fit:* a saddle positioned too high, too far back, too low, or too forward, as well as poorly positioned cleats
- *Pedaling mechanics:* using overly large gears, pulling up or dropping the heel during the pedal stroke, or angling the knees in or out
- *Muscle imbalance and inflexibility:* tight hamstrings and/or weak gluteus muscles
- *Tissue changes posttrauma:* scar tissue, swelling, and/or atrophy from a previous injury

Treatment

First-aid strategies for tendinitis are similar to those for anterior knee pain. Bike-fit strategies include the following:

- Lowering and/or moving the saddle forward for hamstring, ITB, pes anserine group, Achilles tendon, or tibialis anterior symptoms
- Raising and/or moving the saddle back for patellar or quadriceps, or Achilles tendon symptoms
- Proper cleat alignment for appropriate lower leg tracking and force distribution

Pedaling strategies include increasing the cadence by decreasing the gears, practicing single-leg intervals to balance the pedal stroke between the legs, limiting the amount of heel drop, or pulling on the upstroke. Rehabilitation exercises should include stretching tight hamstrings, as these can result in a functionally high saddle position (compared with positioning based on leg length) because of restricted knee extension. Stretching should also target any tight calf, quadriceps, or hip muscles. Strengthening weak gluteus muscles will decrease overdependence on the hamstrings or quadriceps during cycling. If symptoms persist or worsen, visiting a medical professional is recommended.

Neck Pain

Neck pain during riding is reported at the base of the neck or at the base of the skull. If symptoms radiate into the arms (numbness, pain) or lead to weakness, seek a qualified health care provider for advice as this may indicate more serious pathology. Causes include the following:

- *Posture:* a forward head position or insufficient or excessive cervical lordosis (forward curve)
- *Improper bike fit:* stem too long, bars too low, or a forward-tilted saddle
- *Muscle imbalance:* weak or tight cervical and upper back muscles
- *Disk or joint pathology*
- *Inadequate training:* increasing the ride time too fast

Treatment

First aid involves ice or heat, acetaminophen, and rest. Bike-fit strategies include the following:

- Shortening the stem length and/or raising the handlebars lessen forward reach and subsequent neck extension. Riding with the hands on the brake hoods also helps avoid this posture.
- Leveling the saddle to prevent forward leaning prevents neck and shoulder strain from increased load bearing.

Rehabilitation exercises include strengthening of the longus colli, upper trapezius, and periscapular muscles, which support the neck, as well as stretching tight muscles. Building endurance on the bike prevents fatigue-initiated strain, making riding more comfortable. If symptoms persist or worsen, visit a medical professional.

Low Back Pain

Cycling-related back pain may be due to the following causes:

- *Posture:* insufficient or excessive lumbar lordosis or thoracic kyphosis
- *Muscle imbalance:* tight hip flexors and/or hamstrings
- *Improper bike fit:* saddle positioned too low or tilted forward, stem too long, or handlebars too low
- *Poor training/technique*
- *Disk or joint pathology*

Symptoms radiating to the legs or any bowel/bladder changes should be discussed with a health care professional immediately.

Treatment

Core stability exercises targeting the abdominals, back extensors, and hips are strongly recommended for both prevention and rehabilitation. Stretching the iliopsoas and hamstrings should be a regular postride strategy. Fit-related strategies include the following:

- The saddle should be leveled.
- The bar/stem should be adjusted to avoid a long or low reach to the handlebars.
- Leg length difference may be an underlying component and may require shims under the cleat to balance the riding position.

Nerve Compression

Nerve compression in cycling typically involves the ulnar and median nerves in the hand. Ulnar nerve compression results in numbness in the ring and small fingers, which usually clears when riding is stopped. Median nerve compression (or carpal tunnel syndrome) is noted in the thumb through ring fingers, the palm, and occasionally the elbow and shoulder and is often worse at night. The following are some of the causes:

- *Improper bike fit:* excessive forward reach, forward-tilted seat, insufficient handlebar padding, and/or improper brake hood positioning
- *Training/technique:* excessive ride length, riding on rough ground, or overgripping the bars

Treatment

Bike fit strategies are as follows:

- Ensure a proper frame size.
- Adjust the stem/bar height to limit pressure on the hands.
- Level the saddle to prevent forward lean.
- Rotate the bars to raise the brake hoods, or tilt the hoods medially.

Improving padding via gloves or bar tape and adding suspension or using wider tires to reduce vibration into the hands can help. With median nerve pathology, night splints can promote recovery by avoiding compression during sleep. If symptoms do not resolve or worsen, medical attention is recommended.

Saddle Sores

Saddle sores are tender bumps in the buttock and groin area, where saddle pressure is supported. This area, during riding, is typically warm and moist, creating ideal bacterial growth conditions. These bacteria enter the glands and cause local infection. Saddle pressure can also block the pores, entrapping bacteria and inhibiting blood flow. The resultant sore makes cycling extremely uncomfortable.

Treatment

The optimal treatment is prevention: removing the cycling shorts after riding, wearing only clean shorts, replacing the worn chamois (the pad in the cycling shorts), and keeping the area dry. Proper fit to address the pressure on the saddle (height, tilt, saddle type) is an important element, and use of chamois creams to reduce friction is often successful. Gradually increasing the riding time allows tissue to adapt to pressure changes. Once a saddle sore occurs, keep the area clean. After washing, dry the area with baby powder (or its equivalent), and later, apply antibacterial ointment. In severe cases, lancing may be required.

Bernard G. Condevaux

See also Abrasions and Lacerations; Acromioclavicular (AC) Joint, Separation of; Bowel Injury; Concussion; Core Strength; Fractures; Handlebar Palsy; Iliotibial Band Syndrome; Lower Back Injuries and Low Back Pain; Neck Spasm; Patellofemoral Pain Syndrome; Shoulder Dislocation; Torticollis, Acute

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Bioenergetics of Exercise and Training

Human activity, in its various forms, requires energy. Exercise involves the use of energy to perform work that propels the body. Training increases the efficiency of this process in various ways. *Bioenergetics* is the study of the formation, conversion, and use of energy in a biological system. Its application in sports relates to how three energy systems, (1) adenosine triphosphate (ATP)/creatine phosphate (CP), (2) glycolytic/nonoxidative, and (3) oxidative, are used.

Energy is stored in the body as fat, protein (muscle), and glycogen (liver and muscle). It becomes incorporated into the body via ingestion and digestion of food. And when it is metabolized by the three energy systems, the by-products include carbon dioxide and heat.

Different activities use various combinations of these three energy systems. For rapid-power activities (i.e., shot put, weight lifting) that last less than 3 or 4 seconds, the primary energy source is the ATP/CP system. For speed activities that last up to approximately 1 minute or less (e.g., 100-, 400-meter runs), the glycolytic/nonoxidative system uses primarily blood glucose and muscle glycogen. For endurance activities (running a mile or longer), the primary energy system will be oxidative, using muscle and liver glycogen, lipids, and amino acids.

Many activities, of course, use various combinations of the three energy systems, more so than others, responding to the constantly shifting demands of the athlete. A soccer player, for example, will constantly be using the oxidative system to keep running during the game. But sometimes, a sprint may be required to defend or attack, and that effort will tap into the nonoxidative glycolytic system. All three systems are always active, however, with the body constantly replenishing their supply of energy and regulating its use.

Thermodynamics

Thermodynamics is the study of energy exchange and transfer; bioenergetics must follow the laws of thermodynamics, as it applies energy toward biological activity.

The *first law of thermodynamics* is that energy cannot be created or destroyed, it can only be changed from one form to another. This implies that the total energy in the universe remains constant. For example, a sprinter uses energy to sprint. This results in the stored form of energy in the form of ATP and glucose being converted to work to moves the athlete and heat that goes back to the environment. On the other hand, if the ATP or glucose is not used for activity, it will accumulate and be converted to a storage form for the body, that is, fat.

As mentioned, heat is released during metabolism that is required to perform work. Heat can stimulate enzyme activity and contribute to an optimal environment for some enzymes, thus responding to the body's demands. But heat's dissipation through the cooling mechanism also expends energy. Cooling is required because excessive heat can inhibit and slow the activity of the body's metabolic enzymes. In terms of efficiency, energy not devoted directly to performance is considered a loss of efficiency.

Adenosine Triphosphate and Creatine Phosphate

ATP and CP are the basic currency of energy to power muscle contractions. The metabolism of glycogen or fat ultimately produces ATP, which muscles can use. ATP is an immediate energy source and the final pathway toward muscle activity.

The study of muscle physiology shows that ATP combines with actin, myosin, and calcium and becomes hydrolyzed to adenosine diphosphate (ADP), to allow contraction and relaxation of muscle fibers.

CP exists in resting muscle and acts as a source of entry to regenerate ATP. CP plus ADP is converted to ATP and creatine via creatine kinase. The enzymes in the ATP/CP energy system act very quickly and are readily available in the muscle cell cytosol.

The amount of ATP and CP immediately available, however, is limited. Beyond more than 1 minute, the muscle will need other sources of energy.

Nonoxidative, Glycolytic System

Glucose and glycogen, in the blood and muscle, respectively, are broken down via glycolysis and glycogenolysis to form ATP and lactate. This occurs without the use of oxygen within the muscle cell's cytosol, thus it is called the nonoxidative glycolytic system. This system can rapidly supply the required ATP and is in close proximity to the contractile elements of the muscle.

The nonoxidative glycolytic pathway produces two ATP and two lactate molecules from one glucose molecule. Although this process is rapid, the amount available to the athlete is rather limited (approximately 3 grams per kilogram of muscle) and is only adequate for events that take less than 1 minute.

The lactate produced can also accumulate in tissue. Previously believed to be only a harmful by-product, lactate in fact can be metabolized by the body via the oxidative system by cardiac and slow-twitch (Type I) muscle fibers. The hydrogen ions accompanying lactate production do, however, inhibit the glycolytic enzymes and interfere with the coupling of calcium with muscle fibers. This acts as a negative feedback or "brake" to limit muscle activity as nonoxidative conditions persist.

Oxidative System

The primary source of energy for our day-to-day activities, as well as any exercise or sport that requires activity beyond 1 minute, is the oxidative energy system. This system, while not as immediate or rapid as the ATP/CP and glycolytic/nonoxidative energy systems, has an abundance of energy sources. The key is the presence and availability of oxygen. This energy system has components in the cytosol as well as the mitochondria. The process is not as rapid but can produce almost limitless energy.

Muscle and liver glycogen, fats, and proteins are all sources for the oxidative system and are in vast supply in stored forms in the body.

The oxidative system releases much more energy in the form of ATP than the ATP/CP or nonoxidative system. For example, 1 molecule of glucose produces 36 ATP with oxidative process versus only 2 ATP and 2 lactate with the glycolytic process. Even more astounding is the use of fat in the oxidative system. Palmitate, a fatty acid, produces 129 ATP.

Training

Training has definite effects both directly on the energy systems and on which systems are used when. Training goals should be targeted toward a specific type of activity. In general, the overall goal of training is improved efficiency, or the ability of energy from metabolism to produce the work desired.

The effect on the nonoxidative energy systems is minimal, and it is the least with endurance training. Weight lifting and power training can slightly increase the stored levels of ATP and CP.

Endurance training decreases lactate dehydrogenase activity, thus reducing the metabolism of lactate in fast-twitch muscles during nonoxidative forms of activity. It changes the isozyme of lactate dehydrogenase to a type that is similar to that of the heart and thus allows the working muscle to take up and use lactate as an energy source as the heart does. Thus, one of the primary effects of endurance training on the nonoxidative system is actually to convert some of the working muscle cells to use the oxidative system.

Lactate, a by-product of the nonoxidative glycolytic system, is available for use by the heart and these muscles for energy under low-oxygen conditions. Lactate can also be used to form carbohydrate via gluconeogenesis. Elite athletes adapt to training by becoming adept at metabolizing lactate, thus improving their "lactate threshold."

The effect of training on the oxidative system is significant. It improves myocardial contractility and size to better deliver oxygen supplying blood to the body. Blood vessels grow and extend into a process called neovascularization to better deliver blood to muscles in need. The neurohormonal system also responds to training by decreasing its response to sympathetic stimuli, resulting in lowered heart rate and reduced carbohydrate breakdown.

The changes at the muscle cellular level are also equally significant. While specific enzyme rates of activity remain fairly constant, the "engine" of the oxidative system, the mitochondria in muscles, becomes packed with enzymes. Mitochondria also develop more elaborate mitochondrial retinaculum to better perform oxidative production of ATP. Muscles also gain greater densities of mitochondria with endurance training, seen vividly using electron microscopy. Glycolytic muscle fibers can also be converted to oxidative fibers with the stimulus of endurance training.

Neurohormonal changes shift the use of energy stores from carbohydrate to fat, delaying the depletion of carbohydrates and taking advantage of the almost endless energy provided from fat. Endurance training shifts the timing of when the body uses one energy system over the other two. With training, the body will continue to use the oxidative fat-burning system at higher intensities (greater $\dot{V}O_2max$). This delays muscle glycogen depletion and fatigue and is known as the "crossover" concept.

Depending on the sport and the level of development of each energy system, an athlete can improve his or her performance by targeting specific energy systems. If oxygen consumption ($\dot{V}O_2max$) has plateaued, the oxidative system is likely to be maximized. In this case, athletes could improve their performance by improving their ability to exercise under nonoxidative conditions with efforts at or above their lactate thresholds. On the same note, if the event is power related, time spent doing low-intensity aerobic exercise will unlikely benefit the athlete.

Conclusion

Bioenergetics is the study of the transfer of energy in a biological system. Bioenergetics and its application to human movement are subject to the laws of thermodynamics. The application of bioenergetics in sports relates to how it develops the ATP/CP, nonoxidative glycolytic, and oxidative energy systems to respond to the demands of athletic activity. For explosive power sports, the immediate energy source of ATP/CP is used. For rapid activities such as the sprints, the glycolytic system quickly produces adequate ATP and lactate to supply the muscles. And for endurance sports, the oxidative system can supply an almost endless supply of energy. Depending on the type of training, these three metabolic systems are stimulated to various degrees to best address the athlete's needs. An understanding of bioenergetics can help develop and refine training programs toward achieving maximal performance.

John K. Su

See also Biomechanics in Sports Medicine; Diabetes Mellitus; Gender and Age Differences in Response to Training; Postgame Meal; Pregame Meal; Vegetarianism and Exercise

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Biofeedback

Biofeedback as an area of inquiry and clinical application in medicine, psychology, and education first appeared in the literature in the 1960s. In 1975, Leonard Zaichkowsky first proposed that biofeedback had strong potential to help athletes self-regulate the psychophysiological processes that interfere with optimal performance. Unfortunately, little has been published on the topic until recently. Because of significant improvements in technology, biofeedback is now an exciting methodology for assessing "mind-body" function in athletes and a method of training athletes to self-regulate stress reactions.

Biofeedback is a technology that uses instrumentation to detect and amplify internal physiological processes in order to make this ordinarily unavailable information available to the individual as "feedback" in a form that is *meaningful, rapid, precise,* and *consistent.* With feedback and the other essential ingredient for learning (i.e., practice), athletes can learn to control or self-regulate essential biological functions such as muscle tension, heart rate, respiration rate, skin conductance, and brain activity.

The Problem of Athlete Stress and Dysregulation

Both beginning and experienced athletes often fail to perform optimally because of self-induced pressure. As such, their mind and body are in a state of disequilibrium, and at critical moments, an athlete may not know how to self-regulate his or her thoughts, feelings/emotions, physiological reactions, and motor responses. Biofeedback technology is the single most efficient way to teach self-regulation. Perhaps the greatest feature of biofeedback instrumentation is that most manufacturing companies have developed software that allows for two separate operations: assessment and training. First, we can *measure, assess,* and *profile* baseline psychophysiological activity in athletes under conditions of rest, competition, and recovery. Second, the technology allows us to train athletes to self-regulate specific biological functions (e.g., excessive muscle tension) that tend to interfere with performance.

Modalities of Biofeedback

1. *Electroencephalography (EEG), sometimes called neurofeedback (NF).* EEG is used to measure brain activity (frequency and amplitude), and as such, we can determine if appropriate parts of the brain (e.g., those regulating coordination or spatial awareness) are active during peak performance or inappropriate parts (e.g., language production, and negative self-talk) are active. Multichannel recording can take place, so it is possible to determine what brain activity is associated with successful performance and what brain activity is associated with unsuccessful performance.

2. *Surface electromyography (sEMG).* sEMG refers to surface electromyography and measures muscle activity in microvolts. This form of feedback allows us to determine if muscles not involved in a particular skill need to be relaxed and those muscles involved in a skill need to fire in the right sequence and with the right amplitude. In addition to using sEMG feedback for training purposes, the information can also provide insight into the athlete's strength and conditioning or the effects of an injury rehabilitation program.

3. *Heart rate (HR).* HR is typically measured by standard electrocardiogram (EKG) electrodes or a photoelectric plethysmography sensor attached to a finger. HR is a measure of both exercise demands and thoughts and emotions. HR and a more recent measure, HR variability, play a large role in the psychophysiological training of athletes.

4. *Respiration rate.* Respiration is usually measured by a strain gauge placed in the thoracic or abdominal region (or both). Respiration rate and amplitude reflect response to the stress of exercise, psychological distress, or poorly learned breathing mechanics.

5. *Respiratory sinus arrhythmia (RSA).* RSA is a measure of the synchrony between heart rate and respiration. When an athlete is in a calm and alert state, the HR rises and falls with each inhalation and expiration.

6. *Skin conductance.* Skin conductance measurement refers to measuring the sweat response and is referred to in the literature as electrodermal response, skin conductance, or galvanic skin response. Low, stable skin conductivity is an indicator of strong autonomic nervous system function.

7. *Skin temperature.* Skin temperature is another measure of autonomic nervous system function

and reflects somatic relaxation (vasodilation) or stress (vasoconstriction) in an athlete.

Assessment and Training Protocols Used in Sports

Sport scientists and sport psychologists using biofeedback assessment and training usually start by getting baseline measures of the athlete using a typical protocol of rest (2 minutes), psychological stress (2 minutes), and recovery (2 minutes). The stressor usually involves the use of a standardized test, such as the Wisconsin Card Sort Test, the Stroop Test, Serial 7s, or a sports video of performance stress. These measures create a psychophysiological profile that allows the sports scientist to design a training program that will enable the athlete to cope with pressure and maintain an optimal psychophysiological state. Should attention, cognition, and decision making show the greatest amount of dysregulation, then the focus of training might be on neurofeedback (EEG). In many cases, however, lack of self-regulation skills is demonstrated in all the modalities, and thus training will be necessary for all modalities.

Training self-regulation using neurofeedback or biofeedback usually begins in the laboratory, in the reclining chair where the assessment/profiling took place. The athlete attempts to self-regulate specific physiological functions either by using the creative software provided by the biofeedback manufacturer or by reviewing DVDs of successful and unsuccessful performance. The goal is to become aware of specific biological reactivity to pressure and learn what the optimal values are when the mind and body are in the "zone." For example, athletes quickly learn about what happens to their physiology when they slow their respiration down to 6 to 8 respirations/minute. They can also become aware of what happens when they view "anger" being displayed in a DVD video clip or when they simply image an emotional/traumatic reaction. After training in the laboratory or clinic, the athlete attempts to replicate these ideal performance states on the playing field. Wireless technology enables monitoring of psychophysiological signals that are presented as feedback to both the athlete and the sports scientist. Self-regulation training is learned through this real-time feedback and continued deliberate or intentional practice.

Evidence of the successful application of biofeedback technology to sports is provided in the Further Readings. Additional documentation can also be obtained from the Thought Technology website (http://www.thoughttechnology.com). One reference points to the successful development of the "MindRoom" by Dr. Bruno DeMichelis with the AC Milan football club. A second story makes reference to the successful biofeedback training of the first ever gold medal winner from India, Abhinav Bindra, in air rifle shooting at the 2008 Beijing Olympics.

Leonard Zaichkowsky and Daniel O'Neill

See also Imagery and Visualization; Kinesiology; Pain Management in Sports Medicine

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Biomechanics in Sports Medicine

The quest to understand and explain the causal factors associated with the injury mechanisms underpinning biological failure are linked to understanding the biomechanics of human movement.

This entry examines the role of biomechanics within the discipline of sports medicine and has an overall aim of providing a meaningful examination of biomechanics and its relationship with sports medicine.

To achieve these aims, this entry has been organized into four sections. First, a definition of biomechanics and its theoretical link to sports medicine is provided. This section also highlights some basic principles of describing athletic movement and the variables associated with injury. It concludes with an outline of the implicit use of biomechanics from the clinician's perspective. The second section builds on this base and details the practical, clinically based relationship that the sports medic has with the biomechanist in the diagnosis and rehabilitation process. This section evolves into a more detailed examination of the sports-specific research that drives clinical applications. With the increase in the availability and sophistication of measurement systems in biomechanics and sports medicine, an overview of the grounded scientific methodologies available to the practitioner and researcher is provided in the third section. The final section examines some of the major theoretical issues associated with the occurrence of injury. This fourth section highlights some contemporary issues within sports medicine, biomechanics, and current research in this field. Concluding remarks look to the future of biomechanics and its role within the discipline of sports medicine.

Biomechanics and Sports Medicine Defined

The origins of biomechanics and the theories that underpin this scientific discipline have emerged from the very beginnings of scientific discovery. In fact, the origins of this discipline can be traced back to the seminal work of Sir Isaac Newton. who, from the shoulders of other great scientists, produced the *Philosophiæ Naturalis Principia Mathematica* (*Mathematical Principles of Natural Philosophy*) in July of 1687, which provides the foundation of many concepts in use today. In the late 20th century, classical definitions of biomechanics provided by James Hay, Herbert Hatze, and, more recently, Benno Nigg are similar in that they point to a science that examines the forces acting on and within biological structures and investigates the effects produced by such forces. Today, there are many thousands of researchers involved in biomechanics, working toward enhancing understanding of the topics related to human movement, ranging from injury to clinical assessment, ergonomics, rehabilitation, and sports. In the context of sports medicine, biomechanics encompasses a number of fundamental areas, including the study of the functioning of bodily structures (e.g., muscles, tendons, ligaments, cartilage, and bone) and their responses and adaptations to loading in sporting performances.

While it is not the intention of this entry to provide a detailed account of the biomechanics of the musculoskeletal system, knowledge of some of the key principles is necessary to develop an understanding of the mechanisms that underpin the occurrence of injury.

Key Biomechanical Principles

The constituent components of the human body comprise active (force producing, i.e., muscle) and passive (bone, cartilage, ligaments, tendons, and other soft tissues) structures. The interaction of these biological materials, which makes up the joints and the skeletal system, functions in a synergistic fashion, responding to forces and the environment. In sports, this environment can be more predictable (e.g., landing from an apparatus in gymnastics or performing a pitch in baseball) or less predictable (e.g., cutting in football or being checked in hockey). The nature, etiology, and complexity of an injury are based on a number of anatomical, physiological, biochemical, and biomechanical factors. Understanding the factors associated with the occurrence of sporting injury from a biomechanical perspective requires a detailed understanding of the biology and mechanics of human movement, which lies outside the scope of this entry. But some of the key principles that help provide a context within which it is possible to explain the issues relating to the interface between sports medicine and biomechanics are discussed here.

An understanding of the movement patterns and body positions involved in sporting technique is the first step in explaining how athletes achieve performance and also how these movements and positions predispose them to injury. The description of the geometry of movement is known as kinematics (see Figure 1) and includes variables such as time, displacement, velocity, and acceleration. The forces producing movement are known as kinetics, and these include external forces, such as ground reaction forces in running, air resistance, and gravity, and internal forces, such as joint forces and moments. The characteristics of force, which are linked by many to the occurrence of injury, are highlighted in Figure 1 and include peak force and loading rate.

The calculation of internal joint kinetics (joint forces and joint moment or torques) is based on Newton's second law of linear and angular motion using the iterative process of inverse dynamic modeling. Inverse dynamics requires knowledge of the kinematics of the segments, inertial characteristics, and known external forces, usually ground contact:

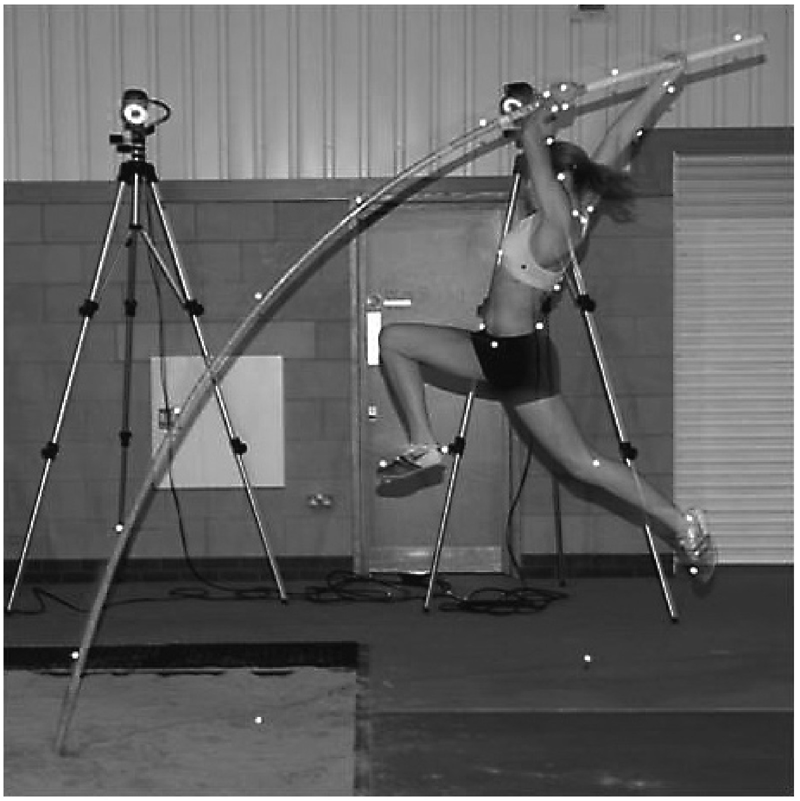
$$\text{Internal joint forces} = \sum F = m \times a$$

and

$$\text{Internal joint torques} = \sum \tau = I \times \alpha,$$

where F = force, m = mass, a = acceleration, τ = torque, I = moment of inertia, and α = angular momentum.

Three-dimensional inverse dynamics provides a measure of the net joint kinetics for extension or flexion, internal or external rotation, and abduction or adduction. These values are very useful in determining whether the technique is overloading the



Kinematics		*Kinetics*	
Temporal characteristics of movement	Timing of phases of a skill	Ground reaction forces	F_z = vertical force F_y = horizontal force F_x = medial lateral force
Displacements	Including joint angles, e.g., extension or flexion, internal or external rotation, abduction and adduction	Force characteristics related to injury	F_{max} = maximum or peak flow F/dt = rate of force application $F \times T$ = impulse
Velocity	Linear and angular: including rate of joint opening and closing	Internal joint kinetics	
Acceleration	Rate of change of velocity		

Figure 1 Key Biomechanical Variables Associated With Describing the Movement Pattern of Performance (Kinematics) and the Forces Involved (Kinetics)

Source: Courtesy of Ray Edwards, Cardiff School of Sport, Biomechanics Laboratory, U.K.

Notes: Also highlighted are the force characteristics that have been associated with injury. In all cases, the displacement, velocity, and acceleration can be either linear or angular.

biological structures of a joint; however, the main problem is in determining what constitutes the limits. Other variables of interest that can be calculated from the joint moments include joint moment power and work, and consequently, a more detailed explanation of the musculoskeletal demands of sporting techniques can be given. The calculation and analysis of joint kinetics require specialist measurement systems and an in-depth biomechanical knowledge of human movement. For the biomechanist and clinician to have confidence in the conclusions drawn, the quality or sensitivity of the result obtained from inverse dynamics need to be quantified. The calculation of joint kinetics can be particularly challenging in a sporting environment; however, the effort is worthwhile in that ecological validity is maintained.

To provide the reader with the underlying theory necessary to develop an understanding of the responses of biological structures to load during sporting activity and to allow the development of a broad conceptual platform from which to build further knowledge, some key concepts are defined and explained in the following section. The magnitude, location, direction, frequency, variability, and rate of loading are key components in the occurrence of injury. The main variables that are highlighted here are load, stiffness, stress, strain, elasticity, and viscoelasticity.

Load

The sum of the forces and torques acting internally and externally on the biological systems of the body or specific tissue is collectively known as *load*. During athletic performance, body segment orientation, which makes up technique, exposes the athlete to these loads, inducing adaptations, which in the most part are desirable. However, when these loads are in excess of the critical limits of the biological structures (accompanied by other contributing factors, e.g., skeletal geometry), trauma can occur. Load affects the nature and severity of injury and can cause failure in two major ways (Figure 2).

Stiffness

The relationship between force and displacement defines the *stiffness* of a tissue. In general, when tissue is deformed within its elastic limit (i.e., the point at which a material subjected to a higher stress will no longer return to its original shape), a linear relationship occurs, with the gradient representing the stiffness. The steeper the slope of the force displacement curve, the stiffer a material will be.

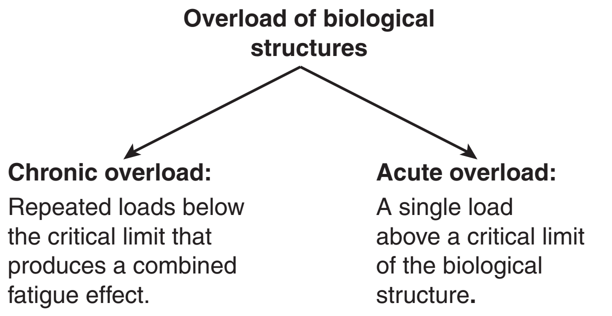


Figure 2 Simple Definition of Overload of Biological Structures

Stress

The internal resistance to load is specific to the tissue experiencing it (bone, skin, cartilage, etc.), and it is this resistance that is termed *stress* or *mechanical stress*. Stress (σ) is defined as the force in newtons (N) per unit area in square meters (m^2):

$$\text{Stress}(\sigma) = \frac{\text{Force}}{\text{Area}} = \text{N/m}^2.$$

Strain

The geometric response of tissue under the influence of load is described as deformation and defined as *strain* (ε):

$$\text{Strain}(\varepsilon) = \frac{\text{Change in length}}{\text{Original length}}.$$

The rate of change of strain over time is also an important mechanical characteristic of biological structures.

The relationship between stress and strain, with regard to load response, is complex for most biological tissues. The ratio of these two parameters defines the elasticity or elastic modulus (E) of the structure:

$$\text{Elastic modulus } (E) = \frac{\text{Stress}}{\text{Strain}}.$$

The two-dimensional loading model is an oversimplification. The compliant yielding phenomenon that characterizes most biological tissue is complex, affected by a number of internal and external factors, and three-dimensional in nature.

Viscoelasticity

The pathomechanics of injury are inherently linked to a tissue's *viscoelastic response*. The viscoelastic characteristics of tissue are related to the constituent matter, specifically the fluid components. The major underlying concept here rests with the fact that the rate of strain causes different stiffness characteristics of the same tissues. In practical terms, what this means is that the faster a tendon is loaded, the stiffer it will become compared with the same tendon loaded slowly. This factor highlights the importance of loading rate as a characteristic of injury potential.

The added complication that a sports medic must take into account is the performance aspects of the athletes in his or her charge. With the complex and specific nature of many sporting techniques, in terms of movement patterns, the loading diagnosis and assessment of injury provide a challenge. Biomechanics within this context can be helpful, to the sports medic, through the development of biomechanically specific tacit knowledge and clinical understanding. The development of a conceptual understanding provides knowledge that practitioners use on a day-to-day basis to inform their decisions and to develop greater knowledge through continued professional development. Examples include the following:

- Peer-reviewed journals provide specific information relating to sporting injury and medicine (including outlets such as the *International Journal of Sports Medicine,* the *American Journal of Sports Medicine,* and the *British Journal of Sports Medicine*).
- International and national conferences—for example, the American College of Sports Medicine (ACSM) and British Association of Sport and Exercise Medicine (BASEM)—have sections dedicated to research in biomechanics and injury. In addition, dedicated conferences on biomechanics and sports have various injury themes that can add to the knowledge base.
- Formally taught courses, generally at the master's level, provide advanced subject-specific knowledge in gaining experience of biomechanical systems, the underlying theory, and its application to sports medicine and injury.

Biomechanists work alongside sports medics in a clinical environment to diagnose, monitor, and understand injury and inform the rehabilitation processes. The ways in which researching biomechanists, often at a university, address sports medicine questions in an ecologically valid setting is dealt with in the following section.

Practical and Clinical Applications

This section details the "day-to-day" methods employed by biomechanists in the assessment of the parameters that play a role in the etiology of injury. Whether it is an analysis of walking, running, or complex gymnastic skills, information regarding the biomechanics of movement can be useful in the search for the causal mechanisms of injury. Understanding the "normal" sporting biomechanics of a skill is the foundation of the application of injury prevention strategies. However, one key principle to consider is the definition of what constitutes "correct" or "normal" biomechanics. An alternative mindset may be to consider the atypical biomechanics of technique that takes into account individual differences in the morphology, physiology, and biological variability of movement. The latter of these issues will be discussed in the final section as an important contemporary issue in relation to the functional aspects of performance and injury reduction. There is evidence to suggest that small changes in the correct or common techniques used in sports activities can lead to injury. The mechanisms that cause this injury are still not well understood, and the issue of which biomechanical variables are responsible for certain sporting injuries is still under much debate. However, with the development of technology and the increased level of fundamental research in the area, more is now understood about the mechanisms of injury. Working with a biomechanist in a clinical environment to diagnose, monitor, and understand injury and also inform rehabilitation may include the analysis of the kinematics of movement, for example, gait, throwing, and running. These analyses may employ simple semiqualitative methods or sophisticated automated motion analysis systems. The measurement of other variables such as ground reaction forces via force plates and pressure distribution through insoles or pressure plates may also be useful. The measurement of external forces can be combined with the inertial characteristics of the athlete and their kinematics to estimate loading at the joints (inverse dynamic analysis). Electromyography can also be used to examine the activation characteristics of specific muscle groups. Variables associated with injury can be measured, analyzed, and monitored by the biomechanists to help inform the decisions of the sports medic. The following section draws on running injuries to illustrate the close relationship between the biomechanist and the clinician.

The Use of Clinical Gait Analysis

The *gait cycle* is the basic measurement unit in gait analysis. From a clinical perspective, gait analysis of walking, running, and sprinting can provide useful information about the occurrence of atypical techniques that produce kinetic and kinematic changes that may influence the type, severity, and nature of injury. The underlying theory that supports this type of analysis will be discussed in the final section of this entry. According to researchers like Professor Tom Novacheck and sports medicine texts, the gait cycle is defined from the discrete variables of foot-ground contact to the next ground contact off of the same foot. The foot contact is vital to the definition of gait. During waking, the heel (subtalar joint) usually may be used by the biomechanist to define foot contact; however, as the speed of movement increases and walking becomes running, different sections of the foot may define the start and end of these phases, including the mid- and forefoot. Indeed, during elite sprinting with velocities in the range of 9 to 12 m/second, the ground contact of the metatarsal-phalangeal joint will be used to define these phases. Copious amounts of literature, from both applied sports biomechanics and clinical biomechanics, detail the key variables used to detect and diagnose the etiology of injury in running. Many disorders of the lower limb have been associated with the orientation of the foot described by its kinematics and the loading of foot and ankle measured via joint kinetics. Literature in this area has highlighted the effect of excessive foot pronation. The impetus behind this view has been the empirical and clinically driven evidence. Nearly a decade ago, Professor Tom Novacheck, stated that there was little grounded scientific evidence to quantitatively support the influence of pronation and that further research into the mechanism associated with injury needed to be carried out. Information gleaned from the analysis of gait can be in the form of kinetic and kinematic profiles detailing specific features of the performance. These may typically include an examination of the level of pronation, inversion, or eversion. Moving up the lower limb to the knee, the clinician would typically be interested in the magnitude of the turning forces at this joint in terms of abduction or adduction, internal or external rotation, and horizontal draw force as an indicator of a potentially hazardous technique. The main issue here is identifying the critical limits of biological structures. The limits of selected biological structures have been reported, but much of this is based on cadaver studies and may have limited use in a sporting or in vivo situation. To overcome these limitations, comparative examinations of the biomechanics of performance are often undertaken, for example, before and after surgery or before and after participation in rehabilitation programs. Feedback to clinicians based on these biomechanical assessments exists on a continuum from qualitative video-based feedback (Example 1) to a more complex and detailed kinematic and kinetic feedback based on automated motion analysis systems (Example 2).

Example 1: Qualitative Video-Based Feedback

A simple analysis of digital video pictures highlighting key instances in the gait cycle is often done by the biomechanist. Comparing the intrasubject variations over a period of time—for example, before and after injury or rehabilitation—will allow the biomechanist to build a picture of the athlete's individualized technique and, using knowledge of the biomechanics of human movement, draw conclusions useful to the clinician. Figure 3 shows some examples of the key variables previously associated with the etiology of injury. Pelvic stability and orientation from simple visual inspection and best-fit angle estimation are shown in Figure 3c. Foot orientation and lower-limb positioning are shown in Figure 4. These images can help indicate a potentially hazardous technique and the mindset of factors that may influence an athlete's predisposition to become injured.

Example 2: Quantitative Feedback

Detailed kinematic and kinetic analysis can provide useful information to the clinician regarding the techniques used in sports performance, and they can highlight areas of concern. A major problem facing the sports medic and the biomechanist is the identification of what could be the causes of injury. This is overcome by a longitudinal approach whereby a profile is built up of the "typical" pattern of movement over time for an individual

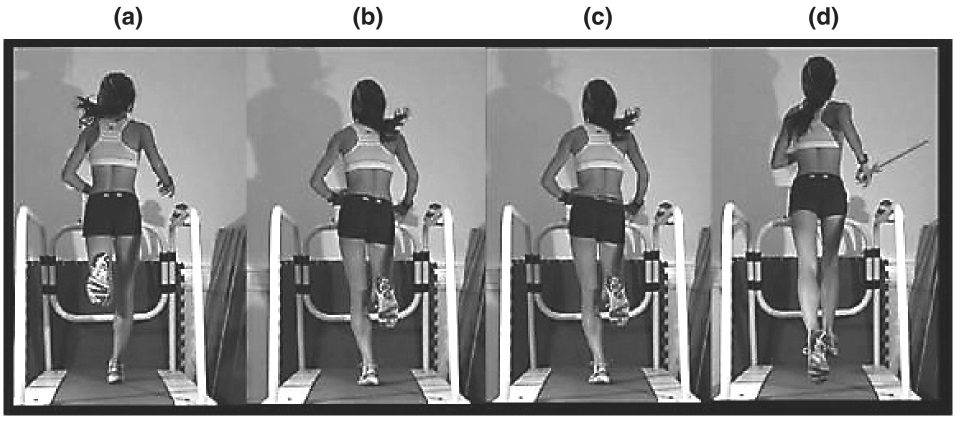


Figure 3 Stop-Motion Photographs Suggesting Weak Hip Extensors and Trunk Muscles

Source: Courtesy of Dr. Ceri Diss, University of Roehampton Biomechanics Laboratory, U.K.

Notes: (a) Midstance with good pelvic stability, (b) midstance showing poor pelvic control, (c) midstance showing poor pelvic control with qualitative measurement, and (d) the resulting upper body rotation during the flight phase, suggesting weak hip extensors and deep trunk muscles.

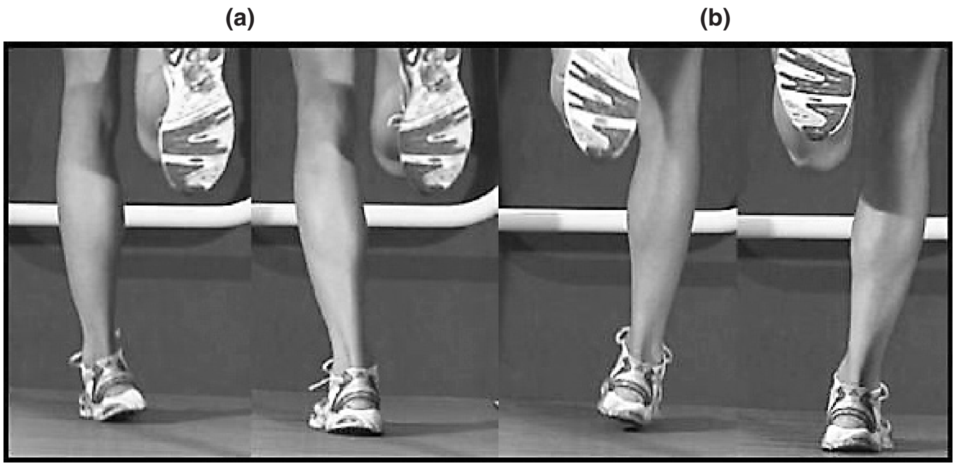


Figure 4 Stop-Motion Photographs Suggesting Foot and Limb Pronation

Source: Courtesy of Dr. Ceri Diss, University of Roehampton Biomechanics Laboratory, U.K.

Notes: (a) Touchdown and midstance of left foot, showing midfoot strike, and (b) touchdown and midstance of right foot. These images provide an indication of pronation of the foot and lower-limb orientation at discrete intervals of time.

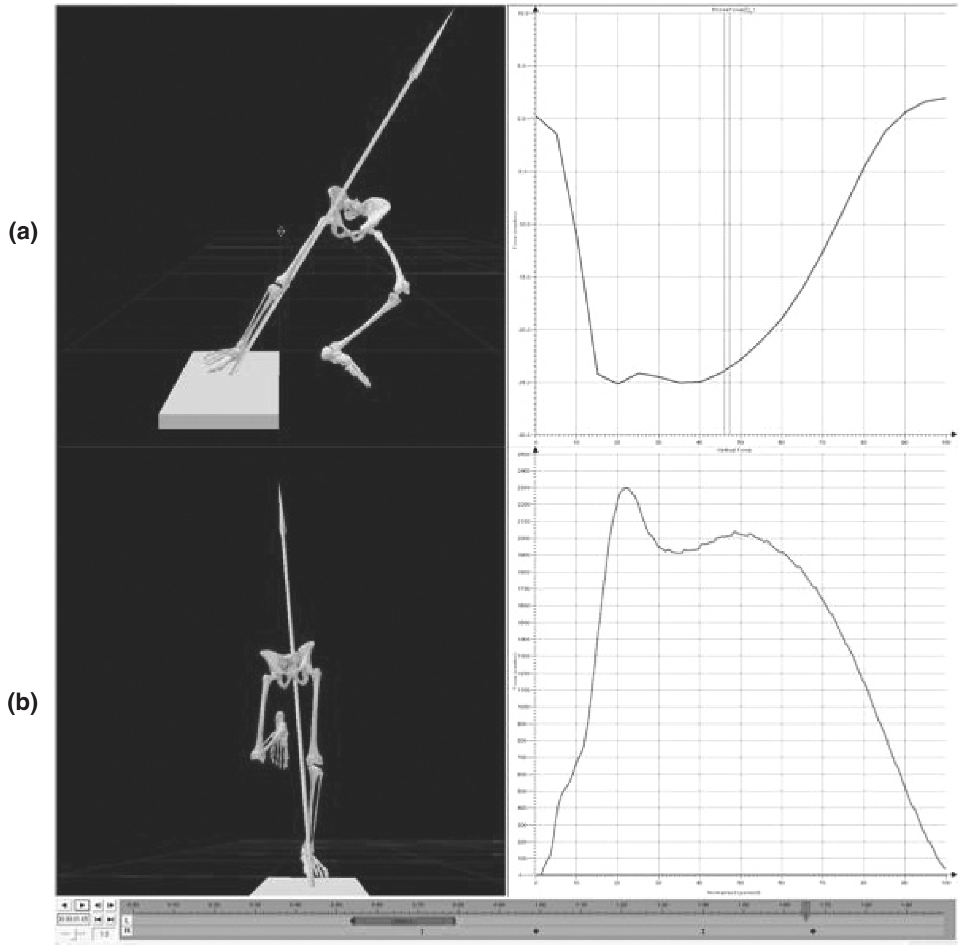


Figure 5 Three-Dimensional Knee Representation Showing (a) Internal Joint Force and (b) Impact Force

Source: VICON polygon viewer, Oxford, U.K. Courtesy of Dr. Ceri Diss, University of Roehampton.

Note: Three-dimensional skeletal representation of a cutting movement with synchronized resultant ground reaction force vector (*top left*), internal knee joint force (internal/external rotation) (*top right*), three-dimensional skeletal representation of running with synchronized resultant ground reaction force vector (*bottom left*), and vertical ground reaction force profile (*bottom right*), showing a distinctive high-impact peak followed by a smaller peak approximately 50% through the stance phase.

performer. Then, any changes that occur in both kinematic and kinetic variables of interest may be markers for biological failure. The images in Figure 5 show two types of fine-grained biomechanics data, which includes a three-dimensional (3D) graphical image of the athlete with the force vector. The skeleton represents the movements of the joints and segmental orientations based on the athlete's anthropometric information. The graphs accompanying the images provide accurate information about the biomechanical variables of interest, which include the internal/external knee forces and vertical ground reaction forces. The biomechanist and clinician will use this information to discuss any atypical aspects of technique.

Clinical examination and critical reflection on patterns of injury, combined with epidemiological evidence, may lead to sport-specific research questions. These queries drive targeted research, drawing on the expertise of biomechanists and medical staff, requiring them to work together in an interdisciplinary approach. An example will now be detailed of how this relationship has worked in the sport of football with reference to boot selection and potential knee injury risk.

Sport-Specific Example: Football

Background. The introduction of bladed football boots in the early 1990s appeared under the marketing banner of a new technology that improves performance in kicking, stability, and maneuverability. Soon concerns emerged through the increased incidence of lacerations and compression injuries, with possible links to knee injury. These issues were highlighted when the English Football Association sent a dossier to the Fédération Internationale de Football Association (FIFA) in 2002 outlining their concerns. Clubs, coaches, managers, and players developed mindsets based on their own experiences. The current example details a national team physician who approached a sports biomechanist to address these concerns.

Research Review. Probably the most common injury of the lower limb in sports that require running, cutting, turning, and stopping is anterior cruciate ligament (ACL) injury. In football, lower limb injuries are very common, ranging from acute macrotraumas to chronic overuse injuries. Specifically in football, knee injures account for about 75% of all lower limb injuries. The football boot undersurface and foot fixation are key components that have been associated with knee injury. In football, more than 60% of ACL injuries are noncontact in origin, and it is well-known that internal tibial rotational moments play a major etiological role. Based on ACL critical limits, this study evaluated commercially available studded and bladed football boots to determine whether the type of boot undersurface affects noncontact ACL injury potential when football players sidestep or "cut" as they run.

Method. To address this research question, a sound, rigorous research design was required. Fifteen professional outfield male football players of mean age 19.5 ± 1.4 years, mass of 70.1 ± 7.6 kilograms, and stature of 1.76 ± 0.06 m, without a history of lower limb injury, and with at least two consecutive injury-free seasons participated. Each undertook three trials of a straight-line run (0°) and sidestep cuts at 30° and 60° on an artificial football surface (FieldTurf FTS01, FieldTurf, Montreal, Canada) approved by FIFA with approach velocity from 5.5 to 6.0 m/second (Figure 5). Each participant was tested using two plastic-studded football boots (Adidas Copa Mundial and Nike Air Zoom Total 90 v3 FG) and two plastic-bladed boots (Adidas Predator Pulse FG and Nike Mercurial Vapor v2 FG), all specified by their respective manufacturers for use on the surface (Figure 5). Kinematics (8 camera VICON 612, Vicon Motion Systems Limited, Oxford, U.K.) synchronized with force plate (Kistler 9287BA, Kistler, Alton, U.K.) data provided inputs for the 3D inverse dynamics analyses (Figure 6).

To enable analysis of potential ACL knee injury, mean absolute externally applied internal/external tibia axial moments, abduction/adduction moments, and anterior forces were calculated. All joint kinetics were normalized to body mass.

The results are displayed in the muscle moment profiles, which provide an indication of the continuous change in musculoskeletal loading, as illustrated in Figure 7. Clear differences can be seen in internal tibial and abduction/adduction moments between straight-line running and cutting at 30° and 60° ($p<.01$).

Figure 6 Research Study of Boot Undersurface and ACL Injury Potential

Source: Courtesy of Dr. Raj Kaila, University of Wales Institute, Cardiff. *Biomechanics of the football cutting manoeuvre: Influence of the football boot undersurface and cutting angle on potential knee injury* [master's thesis]. Cardiff, UK: University of Wales Institute; 2005.

Note: Studded boots: Adidas Copa Mundial and Nike Air Zoom Total 90 v3 FG, bladed boots: Adidas Predator Pulse FG and Nike Mercurial Vapor v2 FG (*top left*); VICON marker placement in a stationary and dynamic situation (*top middle*); VICON output animation (*top right*); and data collection setup showing VICON cameras, the participant, and 3G artificial turf (*bottom image*).

Interestingly, there were no significant differences in key variables between any of the boots, suggesting that the undersurface during this cutting movement was not affected by the use of blades or studs. Therefore, varying the soccer boot type had no effect on knee loading for each maneuver, but sidestep cutting significantly increased internal tibia and abduction moments and anterior joint forces when compared with straight-line running. The clinical relevance of these findings points to the fact that irrespective of the type of soccer boot worn, loading at the knee remains consistent and that player-specific profiles would provide useful information in developing a picture of the typical movement patterns and loadings of these players.

Other important questions also emerged from these investigations, which were used to inform future work on issues surrounding gender, level of performance, fatigue, and anatomical difference. The research described here was collaborative work carried out by Dr. Rajiv Kaila, MRCS, Dr. Gareth Irwin, and Prof. David G. Kerwin at the Cardiff School of Sport and was published by the American Orthopaedic Society for Sports Medicine's *The American Journal of Sports Medicine*. The work also featured in a number of international

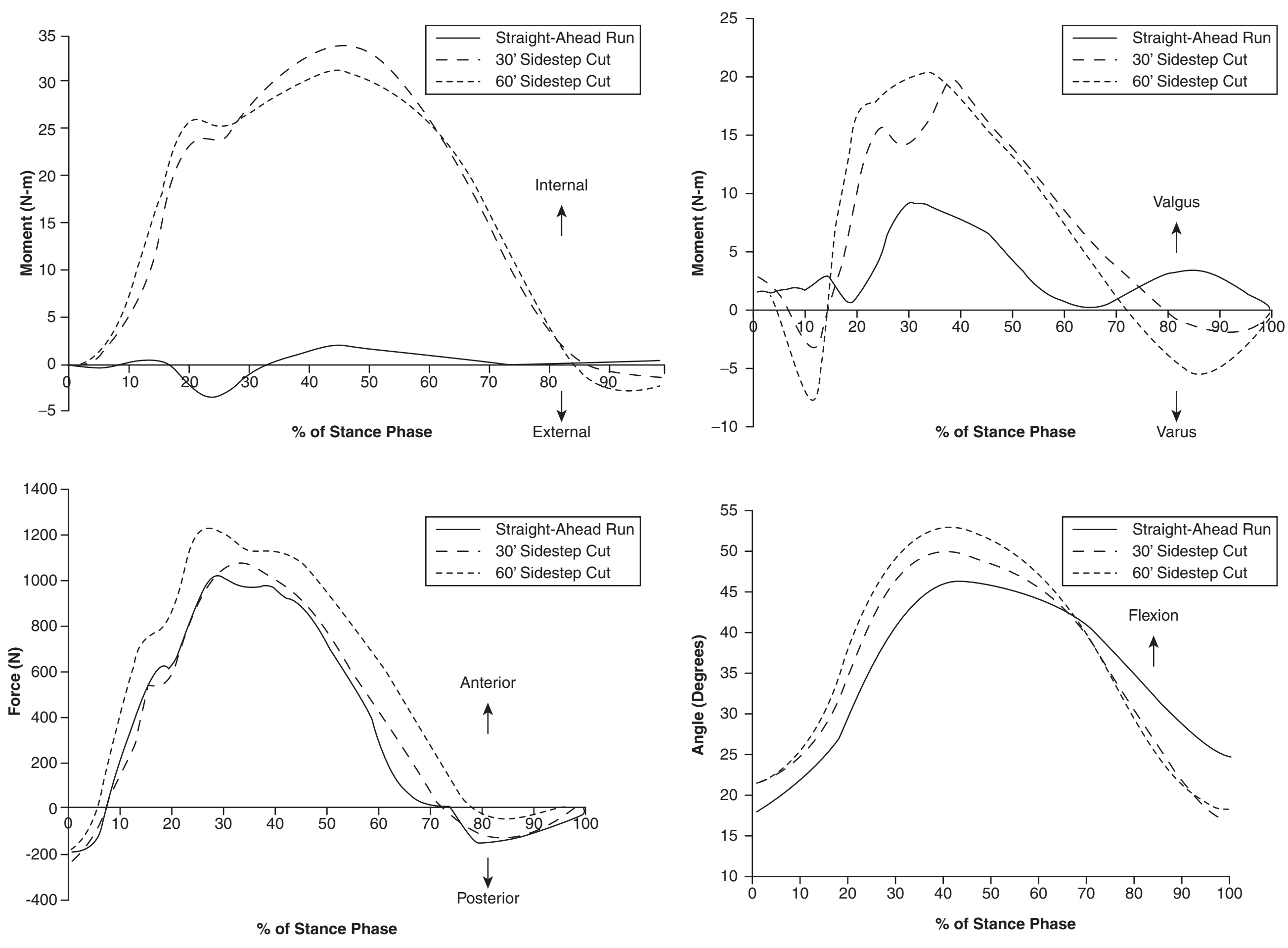


Figure 7 Knee Mechanics During Straight-Line Running and Cutting at 30° and 60°

Source: Courtesy of Dr. Raj Kaila, University of Wales Institute, Cardiff. *Biomechanics of the football cutting manoeuvre: Influence of the football boot undersurface and cutting angle on potential knee injury* [master's thesis]. Cardiff, UK: University of Wales Institute; 2005.

Note: Internal/external moment (*top left*), abduction/adduction moment (*top right*), ground reaction force (*bottom left*), and flexion/extension angle (*bottom right*).

conferences—on both medical and sports biomechanics—and in a keynote lecture at the annual conference of the Royal College of Surgeons and the Football Association in 2006. Details of all these have been included in the Further Readings.

A key issue for the clinician is obviously the logistics of employing a biomechanist to undertake such extensive analyses, even in a video-based gait laboratory. The development of technologies has helped this process significantly over the past 5 to 10 years with the availability of measurement systems. The next section will explore these technologies and explain what tools are available to the modern sports medic and biomechanist.

Methodological Approaches and Issues

To fully understand the extent of the integration of biomechanics into sports medicine, one must first appreciate the technologies that are available to the biomechanist. As in all research, the question dictates the method. It is important that the methodological approach is also underpinned by the grounded scientific principles of accuracy, precision, reliability, and validity. The levels of analysis available, in detail and quality, exist on a continuum with the more simplistic qualitative systems at one end and the advanced automated quantitative systems at the other. Accompanying these analyses is a theoretical or modeling approach. Each will be briefly considered here.

Qualitative Analysis

Over the past decade, there has been an increase in computer and video technologies that have provided the opportunity for clinicians and biomechanists to access a whole range of new techniques for analysis. The development in technology has meant that these systems have become readily available to all interested parties. These systems enable discrete high-resolution images to be selected for instant replay, slow motion, and frame-by-frame playback for use by the clinician or biomechanist. These forms of analysis are normally undertaken in the clinic and allow inspection of key phases of performance and also facilitate comparisons across trials. The main strength of such systems is that they supplement and enhance direct observational skills and provide an excellent archive for future trend analyses. The clinician develops an understanding of what he or she considers to be the desired technique and, by using new technologies, has additional ways of comparing current performances with the mental image of the ideal performance.

The accuracy and effectiveness of any decisions made at this level of analysis, however, can only be as good as the mindsets and conceptual understanding of the biomechanists and clinicians involved.

Semiquantitative Analysis

This level of analysis requires a closer working relationship between the biomechanist and the clinician and is the first step to full quantification. More detailed visual analyses provide improved estimates of the key variables associated with injury. Care has to be taken when using semiquantitative analyses as only simple scaling (i.e., using a single object of known length to convert measures in the video image to real distances) can be achieved. Also, movements are largely assumed to occur in a plane when, in reality, they are 3D. These inaccuracies are exaggerated particularly in the estimation of angles. The validity of many measures recorded using semiquantitative (and qualitative) analyses is therefore questionable. Qualitative and semiquantitative analyses then, although visually impressive and informative, do not provide clinicians and biomechanists with the maximum benefit to be derived from such technology.

Quantitative Analysis

The past decade has seen the rapid development of sophisticated automated motion analysis systems. These systems can provide the biomechanist with the opportunity to collect fine–grained, accurate data ranging from linear and angular kinematics to external forces, internal joint forces, and muscle moments. These systems have also enabled users to calculate muscle power and work, in at best real time and usually within a few minutes of collecting the data. The operation of these systems requires a considerable step-up in knowledge and associated analysis procedures. For sports medicine to benefit from the fruits of this category of analysis, close cooperation between clinicians, coaches, and biomechanists is necessary. The computation of angular and linear, planar, and 3D movements (kinematics) and forces (kinetics) has allowed the biomechanist to develop a larger base of experimental investigations that have increased the understanding of injury.

These systems have been combined with other clinical applications such as radiographic imaging, electromyography, and in vivo force measurements to provide further understanding of the biological processes underlying the potential causes of injury. Innovative analysis methods have emerged alongside these advances in technology. Kinematically, these have included examinations of continuous and discrete inter- and intrasegmental coupling as an assessment of coordination. Exciting new advances in the area of motion analysis include the introduction of machine vision technology, which allows the marker free tracking of whole-body movements. In a sporting situation, this is attractive as it maintains ecological validity and therefore increases the meaningfulness of the derived data.

Modeling in Biomechanics

The computer modeling referred to here is the forward dynamic approach. Forward dynamics modeling is a useful tool in the quest to understand and explain the mechanisms underpinning the occurrence of injury. Biomechanists use the Newtonian laws of motion to produce mathematical formulations to define the systems. Then these models make predications about the behaviors of the biological systems under investigation. There are a number of commercially available software packages that allow biomechanists to build their own models based on specific research questions. Gross models of the whole human can provide useful information about the responses to a technique from a biological sense. A major issue surrounding human models is complexity. The athlete can be simplified, but the model still needs to be representative of a system of rigid and wobbling mass parts linked by springs with varying stiffness and damping characteristics. The type of mathematical representation of human muscle is important and should include the complex dynamics of skeletal muscle force profiles. Modeling of tissues can employ finite element analyses. This technique originated from the necessity to solve complex problems relating to the elastic and structural characteristics of materials. These analyses can inform the researcher about load distributions and subsequent biological responses. Modeling plays a major role in sports and represents a powerful tool; it is often considered the only true method for identifying the individualized optimal technique for a particular athlete.

Contemporary Issues

This section provides an overview of two key contemporary issues relating to the biomechanical aspects of injury. As mentioned earlier, the biomechanist can help in the explanation of the underlying mechanisms that cause jury. Although it must be pointed out that prior to the development of measurement techniques such as inverse dynamics, in vitro force analysis, and forward dynamics modeling, the nature and role of the forces responsible for macro- or chronic injury were not known. Indeed, even today the major contributors to this area—for example, Professor Benno Nigg, Calgary, Canada—suggest that there is as yet no evidence that an increased understanding of load during running has reduced the occurrence of injury. While the relationship between load and injury is still not well understood, there are some key principles and more complex theories currently existing that may help explain the biomechanical mechanisms underpinning the occurrence of injury. Several key concepts have emerged that are fundamental to understanding the etiology of injury. The two concepts that are introduced here are variability and muscle tuning.

Variability

Over the past decade, theories have emerged that have linked biomechanics and motor control. The most well-known of these theories is the dynamic systems approach. Dynamic systems theory has been used to examine and explain injury, particularly of the lower extremities during running. The main researchers in this area are Professors Joseph Hamill, Richard van Emmerik, and Bryan Heiderscheit. This new approach builds on the discrete time research that inked variables such as foot pronation and lower limb internal joint rotation to the occurrence of injury. The dynamic systems approach takes into account the relationship within and between segments during performance, which is quantified through the measurement of joint coupling or coordination. The relationship between injury and coordination variability has been suggested in some cases to be inversely proportional. This is due to the fact that the load placed on biological structures is constantly changing and hence structural failure due to chronic overload is less likely to happen; another benefit of this variability is that it increases the possibility of adapting to any changes in the task (cutting, stopping, and accelerating) or the environment (surface and terrain). This conceptual shift toward the belief that coordination variability has a functional role in the prevention of injury has been controversial within traditional clinical sports medicine. Examining the patterns of coordination and coordination variability through continuous profiling of athletes may allow injury potential to be identified and effective rehabilitation modalities to be monitored.

Muscle Tuning

The main research in this area has been conducted by one of the leading biomechanists, Professor Benno Nigg, from Calgary. He proposed this paradigm based on evidence from epidemiological and experimental studies examining forces. His conclusion is that it was not possible to correlate repetitive-impact forces as a major factor in acute or chronic injuries, specifically in running. The new school of thought proposes that the frequency and amplitude of these impact forces provide an input signal into the biological system. These impact forces produce vibrations of the soft tissue, often referred to as wobbling mass. Skeletal muscle responds to these vibrations in an attempt reduce them. This is achieved through a change in the natural frequency and/or damping characteristics of the muscle, a process defined as muscle tuning.

The strength of this paradigm is that it helps explain the role of impact forces in sporting activities and suggests that they are a prime cause of the development of sports injuries. Additionally, the new paradigm highlights the importance of impact forces as stimuli to the bone. It is also suggested that the impact conditions are correlated to the performance, comfort, and work of the athlete.

The importance of the interface between the surface and the performer becomes more apparent due to the noise removal or filtering effects that the materials will have. This is important in sports such as gymnastics, where epiphyseal growth plate injury can occur at the radius in boys while using the pommel horse apparatus. The resulting ulnar growth creates an abnormal variance in length. The material and geometry of the surface are implicitly linked to the occurrence of such injuries.

Conclusion

This entry has provided an overview of the intrinsically symbiotic relationship that biomechanics shares with the discipline of sports medicine. An initial definition of the science of biomechanics accompanied by the fundamental principles of loading provided the reader with a foundation of knowledge to facilitate further understanding of this area. Practical examples of how the biomechanist can support the clinician to help understand and explain the etiology of injury have been presented, ranging from the viewing of basic digital images to the more complex 3D kinematics and kinetics collected using automated systems. A sport-specific example is then presented that highlights the importance of being able to use research to address sport-specific questions in an ecologically sound fashion. The development of technology over the past 10 years has been dramatic, and an overview of the methods available to the biomechanist has been introduced in this entry. Looking to the future, the entry dealt with two complex issues that are the subject of much debate within the clinical and sports biomechanics community.

Possible future developments are likely to include a stronger mutual relationship between sports medicine and biomechanics. The development of technologies such as machine vision and automated motions analysis systems combined with radiographic and inertial scanning devices will allow more accurate and useful explanations of human movement and loading. These descriptions and explanations when set within a sporting context with a high degree of ecological validity will serve to effectively address problems from a question- rather than a discipline-specific perspective. Bringing coaches, sports medicine experts, and biomechanists together in an interdisciplinary approach will allow the development of this field, which continues to develop through internationalization and broadening of the scientific expertise, to build an outward-facing academic discipline.

Gareth Irwin

Author's Note: The author would like to express thanks to Professor David G. Kerwin and for Dr. Ceri Diss's help in preparing the manuscript and supplying selected images.

See also Orthopedist in Sports Medicine, Role of; Pre-Sports Physical Examination; Risk Factors for Sports Injuries; Sports Biomechanist

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Black Nail

Black nail (subungual hematoma) is a straightforward nail-bed injury manifested by pain and dark red to black discoloration of the nail bed. Black nail is the result of blunt trauma or crush injury to the nail followed by bleeding from an underlying vessel. The nail bed is vulnerable to injury due to its rich vascular supply and its position between the tough nail and hard bone (the distal phalanx). Black nail is also referred to as *subungual hematoma*, meaning a collection of blood (hematoma) beneath the nail (subungual).

Presentation

Black nail appears as a visible area of bleeding between the nail bed and the fingernail. The degree of discoloration can vary, as can the timing of presentation. If the injury is close to the base of the nail (near the cuticle), discoloration may not be visible for several days. However, if the injury occurs more centrally or toward the end of the nail, the discoloration can be seen the same day. Either way, the red, dark violet, or black discoloration persists until the nail plate grows out. In cases where the bleeding is significant, there is a significant risk of losing the nail. The accumulation of pressure can cause separation of the nail plate and loss of the nail.

Traumatic causes of black nail in sports include dropping a weight onto a nail while weight lifting, being hit by a pitch in baseball or softball, and an opponent applying force down onto one's nail (such as in wrestling). Repetitive stress can also cause nail injury, such as the repeated striking of the toe into the end of the toe box in tennis and jogging and the stress placed onto the toes in dancing, particularly when ballet dancers dance en pointe.

Making the Diagnosis

This is a clinical diagnosis, meaning that extra testing or imaging is typically not necessary. The exceptions to the rule are (1) an unstable fingertip, (2) a mechanism of injury that is indicative of fracture (broken bone), and (3) a dark nail that is not painful and is asymptomatic. In the first two scenarios, radiographs should be done to rule out bone trauma. In the last case, it is important to monitor the discolored nail carefully and chronically in order to differentiate black nail from possible subungual melanoma, an invasive cancer. Subungual melanoma will be asymptomatic and nonpainful; there is also typically no history of a traumatic injury to the nail. If a clinician is worried about melanoma, a biopsy may be done.

Lacerations are complications of nail-bed injuries, and they occur in the nail matrix. The degree of suspicion for a laceration rises when 25% to 50% of the nail is discolored by a subungual hematoma. However, they can only be diagnosed by removing the nail plate and examining the nail matrix. This is done after digital lidocaine is applied to the area to anesthetize the nail bed.

Treatment

The severity of the nail injury determines the appropriate treatment for black nail. Treatment options include observation, drainage, and nail removal. Small hematomas involving less than 25% of the nail bed can simply be observed; intervention is typically not necessary. The blood will be integrated into the nail. As the nail lengthens, the blood will progress with the new growth and eventually be removed when the edge is trimmed.

Black nail involving more than 25% of the nail bed should be drained, because pressure accumulates under the nail and causes discomfort. Pressure from large hematomas can even lead to deformity. Decompression is done by creating a hole in the nail near the center of the hematoma. This can be done by melting a hole with a heated needle, a handheld cautery device, or a carbon dioxide laser; a scalpel blade has also been used. However, care should be taken to avoid putting extra pressure on the nail and subjecting the patient to additional pain. It is important that the hole be large enough to allow blood to drain and to avoid being sealed shut by seared blood under the surface. Decompression provides immediate pain relief and quickens the return to athletics and activity (see Figure 1).

In the case of a broken finger, once the hematoma has been decompressed, it is considered an open fracture. Broad-spectrum antibiotics should be given to cover for possible infection and osteomyelitis. Some sources advocate using sterile technique during the evacuation, including surgical scrub of the injured finger. However, this is not the current standard of care. Some severe fractures require removal of the nail plate, irrigation, debridement, and repair of the nail bed. Any black nail involving a fracture requires immobilization by splinting.

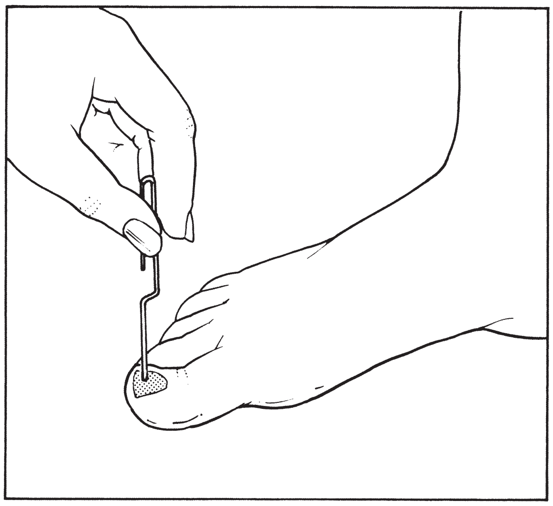

Figure 1 Decompression of a Black Nail

After treatment, the nail should be monitored. The injured nail will eventually detach, and a new nail will grow beneath. In most cases, no further treatment is warranted. Sometimes, the new nail will have bloodstains on it. As with the black nail that does not require treatment, the stains will advance along with nail growth and eventually grow to the nail edge. Complications after decompression include persistent bleeding and development of an ingrown nail. Persistent bleeding raises the suspicion of a nail-bed laceration. As alluded to earlier, the nail should be removed to examine the nail bed and possibly suture the wound. Toe nails are more likely to become ingrown, which results from progressive growth of the lateral nail fold.

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See also Finger Fractures: Overview; Ingrown Toenail

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Bleeding Disorders

Bleeding is commonly understood as a loss of blood from the vascular system either internally in the body or externally through a natural orifice or break in the skin. Normal bleeding time following most soft tissue injuries is less than 5 minutes. Prolonged bleeding time may indicate a bleeding disorder. This entry focuses on how these disorders may concern people who are active in exercise and sporting activities, identifies the sporting events and activities that are acceptable or unacceptable for people with bleeding disorders, and describes how treatment is rendered and how to monitor these athletes on a continual basis.

Normal Bleeding and Clotting

Blood carries vital nutrients within a liquid made up of plasma, red and white blood cells, and platelets. Plasma, a mixture of water, sugar, fat, and protein, also contains many chemicals that help form the clots necessary to stop bleeding. Red blood cells carry oxygen to all parts of the body. White blood cells fight infections and disease. When an injury occurs, platelets gather at the site of the injury and adhere to the edges of the wound, where they release chemicals that help start the process of clotting so that bleeding will stop.

To understand what is *abnormal* bleeding associated with bleeding disorders, we must first understand the *normal* process of how our bodies bleed and clot. Bleeding occurs in approximately four stages. (This process is the same for both external and internal bleeding.)

Stage 1: The platelets in the blood activate and form a plug over the injured skin or vessel. This plug lasts for 12 to 24 hours.

Stage 2: A substance called Von Willebrand factor reacts with the platelets to increase the "stickiness" of the platelets to each other and the surrounding collagen or tissue.

Stage 3: Further platelet recruitment is involved via local hormone messengers such as fibrinogen and thromboxane.

Stage 4: Activation of the clotting factors, produced by the liver, forms a series of reactions and stabilizes the bleed even further. These factors are XII, XI, IX, and VIII to VII and X, and V. Notably, a deficiency of Factor VIII—which is Hemophilia A—is the most common factor deficiency that causes a bleeding disorder.

Common Types of Bleeding Disorders

The three most common bleeding disorders in athletes are as follows:

1. *Von Willebrand disease* (VWD), an inherited disorder of platelet function (reflected by prolonged bleeding time) and a partial deficiency of functional Factor VIII, which occurs in about 1 in 100 people
2. *Hemophilia,* an inherited deficiency of Factor VIII or IX, which occurs in about 1 in 10,000 people
3. *Immune thrombocytopenic purpura* (ITP), which is an autoimmune or drug-induced disorder

Signs of a Bleeding Disorder

Athletes with bleeding disorders may show the following signs:

- Athletes with VWD usually have mucosal (nasal and gastrointestinal) bleeding. In women, it also includes heavy menstruation.
- Hemophilia in contact athletes is characterized by bleeding into a joint cavity (hemarthrosis), such as the knee, or into muscles. Prolonged bleeding times in the face of a skin injury can occur as well.
- Crops of little red blanched dots on the skin known as petechiae, along with purpura or bruising, may signal thrombocytopenia, low platelets, or ineffective platelet function.

Any bleeding disorder may be worsened by the use of aspirin or anti-inflammatory drugs, which can affect platelet function and therefore prolong bleeding. A physician along with a hematologist can diagnose a bleeding disorder. Routine tests such as cell blood count (CBC) will look for low platelets, anemia (low hemoglobin), prothrombin time (PT), and partial thromboplastin time (PTT). Prolonged PTT can be the initial clue in the diagnosis of hemophilia or VWD. Like hemophilia, VWD will have a prolonged bleeding time.

Treatment

Treatment immediately after an injury includes activating the PRICE regimen: *p*rotect, *r*est, *i*ce, *c*ompression, and *e*levation. Athletes with mild cases of VWD are treated with DDAVP (desmopressin), and those with active bleeding are treated with Factor VIII concentrate.

Treatment for hemophilia is often given when bleeding has started or when the doctor knows that clotting factor replacement will be needed, such as before surgery. This is known as treatment "on demand." Recently, however, doctors have started prescribing clotting factor replacement to young people on a regular basis to try to prevent bleeds from starting. The goal is to ensure that joints and muscles are less likely to be damaged in the future. This preventive type of treatment is known as prophylaxis.

ITP is generally limited to children. Cases usually cease when the offending drug is stopped (e.g., antibiotics such as trimethoprim/sulfamethoxazole or vancomycin, or antacids such as famotidine or ranitidine). However, a case was reported of a professional football player who developed ITP after taking quinine sulfate for muscle cramps. In adolescents and young adults, most cases of ITP are autoimmune related and require corticosteroids, IV (intravenous) immunoglobulin, and, in some cases, a splenectomy.

Activity Prescription

Recent decades have seen a shift in attitudes and approaches to bleeding disorders and sports. Formerly, hemophiliacs were overprotected and told to be as physically inactive as possible. In many cases, physical activity was forbidden. They were kept indoors, often not allowed to go to school, and not allowed to engage in activities that could be perceived as high risk.

The main authority on exercise, the American College of Sports Medicine (ACSM), does not publish guidelines on activity and bleeding disorders. Even the *Preparticipation Physical Evaluation* monograph, a guide that helps physicians screen medical conditions during routine preseason physicals in sports, simply recommends further evaluation for anyone with a bleeding disorder. This leaves the decision of whether to participate to the athlete and his or her health care team: the primary care physician, the hematologist, the athletic trainer, and, in the case of children, the parents.

In general, however, athletes with hemophilia and VWD are precluded from contact sports, specifically collision sports such as football, basketball, soccer, and rugby. The research varies, and some experts believe that contact sports may be allowed in mild cases of ITP if the platelet counts are above 100,000 per cubic millimeter.

There is a consensus among physicians that good physical condition and well-trained musculature in athletes can reduce the incidence of spontaneous bleeding. Rochelle Tiktinsky and colleagues observed a marked decrease in bleeding complications among hemophiliacs after progressive resistance training. It has been demonstrated that physical activity enhances the concentration of various coagulation factors without raising the number of bleeding episodes cased by the training program.

Classifying Sports: Contact Versus Noncontact

The medical and sports industries have created ambiguity in defining who may or may not participate in which sports. Some sports have been ranked as high risk based on the frequency of injuries, even though those injuries are relatively mild. Some sports, such as snowboarding, in which the injuries can be catastrophic, are ranked as medium risk. Interestingly, basketball and soccer both appear on the American Pediatric Society list as "contact" or "collision" sports but are classified as medium risk in most hemophilia publications. The need for clarity and consistency to guide athletes and their health care teams is apparent.

What is more important in identifying risk for an athletic patient with hemophilia or VWD is to match the athlete and the activity according to the biomechanical requirements of the sport and the physical abilities of the participant. This is being done in Germany. Biomechanical analysis, including angular acceleration, is measured for different sports to calculate joint stresses. Children with hemophilia are assessed for balance and coordination, flexibility, muscle strength, endurance, and body mass. The results of the assessment are then compared with the demands of the child's chosen sport. If the analysis shows that the joints and muscles are up to the task, the child is allowed to play. If deficiencies are found in certain areas that the sport requires, the child is advised to choose another sport or to correct those deficiencies before trying to play.

Conclusion

Physical activity is advocated for the general population. It has been linked to favorable effects on heart disease, hypertension, obesity, diabetes, osteoporosis, high cholesterol, and emotional states. Through appropriate participation in sports, people with bleeding disorders can develop good physical condition and motor coordination, which may prevent musculoskeletal problems and speed recovery after joint and muscle bleeds. Participation in activities that are normal and desirable parts of social life confers not only physical but also psychosocial advantages.

In any sport or physical activity, those with bleeding disorders need proper physical conditioning. They must know the rules, have the skills to play, go through proper warm-up, and use appropriate protective equipment. Education concerning the player's bleeding disorder is imperative for the coaches, trainers, and parents. Most important, if an injury does occur, proper treatment must be readily available.

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See also Abrasions and Lacerations; Nonsteroidal Anti-Inflammatory Drugs (NSAIDs)

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Blisters

Blisters occur where there is excessive friction over the skin. For this reason, they are frequently called *friction blisters.* This differentiates them from blisters caused by heat or solar injury, infection, medications, or other medical conditions. Friction blisters generally occur on the soles and heels of the foot; however, they may also form on the palms in athletes who are active with their hands, such as rowers and gymnasts. Although more common in active populations because of the repetitive movements in athletics, all people are susceptible to friction blisters.

Anatomy

The skin has three layers. The deepest layer is called *subcutaneous tissue* and is composed of adipose (fat), nerves, hair follicles, arteries, veins, and sweat and oil glands. The middle layer is the *dermis.* It has two layers and varies in thickness depending on the location in the body. The deepest layer of the dermis is composed of thick collagen (connective tissue) fibers, which have parallel alignment with the skin surface. This layer sits just on top of the subcutaneous tissue. The thin, more superficial (outer) layer of dermis is also made of collagen fibers, which are randomly arranged. The most superficial layer of the skin is the *epidermis*. The epidermis constantly replenishes keratinocytes (skin cells), which flatten, die, and eventually slough. The overall thickness of the epidermis depends on its location in the body. It is thickest in the palms and soles. The epidermis consists of five layers (from deep to superficial): stratum basale, stratum spinosum, stratum granulosum, stratum lucidum, and stratum corneum. The *stratum basale* is named for the basal cells that form the base of the epidermis. They lie on top of the dermis, are shaped like columns, and are constantly dividing to replenish the cells lost at the surface. Basal cells divide into keratin-producing cells called *keratinocytes*. These keratinocytes form microscopic spines that link them together; thus, this layer is called the *stratum spinosum*. As the cells migrate toward the skin surface and become progressively flattened, they form a new layer called *stratum granulosum* because the cellular cytoplasm appears granular under microscopy. The cells then die and become the outermost layer, the *stratum corneum*. The *stratum lucidum* is a transition layer between the stratum granulosum and stratum corneum. It is found only in the thick skin of the palms of the hands and soles of the feet. This layer contains an oily substance that provides protection from friction. A friction blister forms when there is breakdown of the spinous bridging in the stratum spinosum. The blister roof and floor contain the normal layers of dermis and epidermis, and the cavity becomes filled with a clear transudate (fluid). If the friction over an area is more intermittent, hyperkeratosis (callus) formation may occur. This thickened area can be somewhat protected from friction blisters. If left to grow thick, however, a friction blister may occur under a callus.

Causes

Any repetitive external force across a localized area of skin can cause a friction blister. Susceptibility is based on the magnitude of frictional forces and the duration of repetition. Athletes are unlikely to stop their activity with the earliest signs of discomfort from friction blisters, thus predisposing them to greater severity. Typical causes are poorly fitting footwear, sweating, heat, and increased level of activity preceding protective callus formation.

Symptoms

Initial symptoms of friction blisters are a localized, mildly erythematous (red) "hot spot" in the area of repetitive friction forces. Slight stinging or burning may be associated with this stage and tends to worsen as the friction forces continue. The localized area becomes progressively more erythematous and painful, and a zone of pallor (white skin) surrounds the area. Eventually, the stratum spinosum splits, filling with a clear transudate. The roof of epidermis skin covering the friction blister becomes raised, tense, and appears white or yellow. A zone of erythema may surround the bullae (fluid filled sac) depending on the amount of irritation. In extreme cases, ulceration may occur in the floor of the bullae, or the protective roof may break, exposing the underlying dermis to infection.

Prevention

Prevention of friction blisters begins with awareness of a localized "hot spot" and then taking appropriate measures to reduce the causative friction force before bullae formation can occur. Choosing appropriate footwear, wearing gloves if using the hands, and gradual entry into new activities are also helpful. Other considerations in preventing friction blisters on the soles and heels are choosing socks that optimize frictional and wicking properties. In general, socks that move moisture away from the skin and can maintain their cushioning despite compression and moisture are the best. These include an outer wool or polypropylene sock combined with a wicking, thin, polyester-base layer sock. Antiperspirants have also been used in the prevention of friction blisters but may be associated with contact dermatitis (skin irritation).

Treatment

Most friction blisters are self-limited and will heal with little intervention once the friction force is removed. If the roof of the bullae remains intact and tense, a doughnut pad can be placed around the site for protection and to relieve discomfort.

The bullae can also be drained using sterile technique; however, the overlying blister roof should not be disrupted as it acts as a protective dressing. If the roof is already removed, the blister should be treated as an abrasion. In this case, an antiseptic and bandage should be applied in addition to doughnut padding. If signs of infection are present, antibiotic treatment may be indicated.

Specialized blister dressings are now available with and without a prescription. They are typically a semipermeable, adhesive film that provides a protective sterile covering for blisters that have lost their roof. In some cases, they are medicated.

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See also Bunions; Calluses; Frostbite and Frost Nip; Irritant Contact Dermatitis

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Blood Transfusion

Blood transfusion is a life-saving technique that was developed in the 1880s. It is used therapeutically to treat anemia but has also been used by athletes as a performance-enhancing technique.

Anemia is a condition in which there is a decreased amount of red blood cells. It is measured by analyzing a sample of blood and calculating a hematocrit (the proportion of blood that is occupied by packed red blood cells). Anemia can develop from many causes: of these, iron deficiency, kidney failure, and blood loss are among the most common.

It may be surprising to some people that transfusions also have been used by some athletes as performance enhancers. Endurance athletes competing in cycling, marathons, or triathlons have been known to use this technique, known as *blood doping*. Blood doping is a way of artificially increasing the amount of red blood cells in the body's circulation. The red blood cells (and the protein *hemoglobin* inside the cells) carry oxygen to all the tissues of the body. The more the red cells and hemoglobin, the more oxygen can be delivered to the exercising muscles. An athlete with more red blood cells can exercise harder and longer, with quicker recovery, more stamina, and better results—up to a point.

Athletes who engage in blood doping put themselves at risk of disqualification and also put themselves at risk for myriad health problems. This dangerous technique creates polycythemia (increased number of red blood cells) and increases the viscosity of the blood, which leads to sludging. Sludging in the heart can lead to myocardial infarction (heart attack), and in the brain it can cause stroke (cerebrovascular accident, or CVA). Sludging in the veins causes blood clots in the legs or pelvis (deep vein thrombosis, or DVT), and pieces of these clots that break off and go to the lungs can instantly kill the athlete (pulmonary embolism). Blood doping can also cause kidney failure and even iron overload toxicity.

Blood transfusions require needles and IV (intravenous) drips. There is an inherent risk of cellulitis or phlebitis (infection from the IV site). In addition, blood products can carry dozens of viruses, such as hepatitis B virus (HBV), human immunodeficiency virus (HIV), and others. Athletes have tried to minimize this risk by taking their own blood out weeks or months before competition (autologous blood transfusion). They store the blood, give their body enough time to bring their blood levels back to normal, and reinfuse the stored blood just before their event.

With this blood-doping technique, there can be problems with sterility and storage, especially if it is being done surreptitiously. Blood is an excellent culture medium, and even small amounts of bacteria that have contaminated the blood can cause deadly sepsis; so can blood that has been improperly stored.

In endurance sports, such as the Tour de France, strict monitoring of hematocrits is used to detect athletes who are blood doping. A normal hematocrit for an average adult ranges from 32% to

43%. Intense exercise over time can increase it up to around 46% or even 48%. If the hematocrit for an athlete is found to be more than 50%, it may be assumed that he or she has used artificial means. In this case, he or she may be investigated further or disqualified.

Other methods besides blood transfusions are used to raise hematocrits, including the use of erythropoietin (EPO). EPO is a chemical that stimulates the body to make more red blood cells and is discussed at length in a separate entry. In addition, people who live at high altitudes will acclimatize over time and will naturally have higher hematocrits. Athletes have tried to harness this phenomenon. Some will live and sleep at high altitudes (and train at sea level) to achieve this effect on hematocrit. Some use hypoxia tents, where they sleep in an environment of slightly lower than normal oxygen levels. This simulates the low oxygen experienced at high altitude. These are considered legal devices; however, their use as performance-enhancing devices is somewhat controversial. Sports-governing groups continue to investigate their safety and effects. The proper use of hypoxia tents is generally considered safe, and they are not banned in any sport.

Michael O'Brien

See also Bleeding Disorders; Doping and Performance Enhancement: A New Definition

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UpToDate for Patients: http://www.uptodateonline.com/patients

Blood-Borne Infections

During participation in athletics, an inherent risk of exposure to, as well as subsequent transmission of, blood-borne viral infections exists for both the athlete and sports medicine team members. Although there are presently no published epidemiologic studies assessing the transmission of viral pathogens such as human immunodeficiency virus (HIV), hepatitis B virus (HBV), or hepatitis C virus (HCV) during athletics, expert opinion estimates the theoretical risk to be exceptionally low. Regardless of the improbability of communication of blood-borne viral infections in sports, the underlying focus should involve preventing the dissemination of blood-borne infections and education of athletes/staff members regarding the potential risks of transmission on and off the field. Emphasis should be placed on off-field conduct and on minimizing risk-taking behaviors, as sexual contact and injection drug use overwhelmingly pose the greatest risks of infection for the athlete. Other challenging facets of blood-borne infections and the athlete involve ethical and legal issues pertaining to disclosure of infection status.

Those involved with the care of the athlete should become more familiar with the following aspects of blood-borne infections in athletic participation:

- Epidemiology and transmission factors associated with HIV, HBV, and HCV infections
- Prevention and educational initiatives involving blood-borne pathogens in the athletic setting
- The role of testing for blood-borne infections in high-risk athletes
- Management issues pertaining to diagnosis and care of the recently infected athlete
- Legal and ethical considerations affecting an athlete infected with a blood-borne pathogen

Epidemiology and Transmission of Blood-Borne Viral Pathogens

Risk of transmission of blood-borne infections can be categorized according to the likelihood of contact and collision in a given sport. Athletes taking part in sports such as wrestling, boxing, and tae kwon do have a higher risk due to significant blood exposure and prolonged close body contact. "Moderate"-risk sports include basketball, field hockey, ice hockey, judo, soccer, and team handball; lowest-risk sports include baseball, gymnastics, and tennis.

Transmission risk during athletic participation stems largely from bleeding wounds or the blood of an infected athlete contaminating the skin or mucous membranes of other athletes/staff members. However, the athlete's greatest risk of acquiring a blood-borne viral infection is through sexual activity and injection drug use rather than through on-field activities. Additionally, the increasing popularity of body piercing and tattooing among adolescents and young adults is another potential means of transmission of viral blood-borne infections. Skin branding, a fashionable practice of college athletes belonging to Greek fraternities, similarly can be complicated by acquisition of blood-borne infections in settings where nonsterile equipment or procedures are used.

Human Immunodeficiency Virus

According to the World Health Organization (WHO), the number of people living with HIV worldwide in 2007 was estimated at 30 to 36 million. These new data represent a significant correction of previous analyses and can be attributed to improved survey data and advances in estimation methodologies. Previous estimations of 36.1 million HIV-infected people in 2000 and 39.5 million in 2006 have been revised to 27.6 million and 32 million infected people, respectively. Globally, it is estimated that 0.8% of the adult population (aged 15–49 years) is infected with HIV.

In 2006, an estimated 56,300 new HIV infections occurred in the United States. Fifty-three percent of all new infections in 2006 occurred in gay and bisexual men, 31% resulted from high-risk heterosexual contact, while 12% of new infections were the result of injection drug use. The number of annual infections peaked in the mid-1980s at approximately 130,000 per year and reached a low of roughly 50,000 in the early 1990s. Incidence appeared to increase in the late 1990s but has stabilized subsequently (in the three most recent periods analyzed, new infections ranged from 55,000 to 58,000 per year).

Presently, no scientific study has specifically investigated transmission rates of HIV among competitive athletes. According to a research conducted by the Centers for Disease Control and Prevention, the risk of HIV transmission during athletic participation is very low. With the exception of boxing, the calculated risk is less than one transmission in 1 million games. To date, transmission of HIV during sports has not been corroborated. In 1990, Torre and colleagues reported one alleged case of HIV seroconversion during a collision between soccer players in Italy. However, the infected athlete's off-field profession (as a drug dependency rehabilitation center worker) and the lack of sufficient documentation to confirm that the transmission occurred during sports participation led public health officials and reviewers to reject the claim as inconclusive and unsubstantiated.

Research conducted with health care workers provides much of the epidemiologic basis for HIV transmission rates and risk. Approximately 1 in 300 needle-stick injuries involving infected blood results in HIV transmission. The risk of transmission from exposure to mucous membranes or nonintact skin has been determined to be 1 in 1,000 exposures, significantly less than the 2 to 3 per 1,000 exposures risk from parenteral (i.e., intravenous, intramuscular, subcutaneous) exposure. Skin and mucous membrane transmission appears to require prolonged exposure to large quantities of blood in addition to a portal of entry (e.g., cuts, abrasions, open wounds), thus making the potential for HIV transmission in typical sports settings unlikely. Casual body contact occurring during athletic participation (e.g., sharing sports equipment, touching, sharing locker room/bathroom facilities, contact with contaminated surfaces such as toilet seats and wrestling mats) poses virtually no risk of HIV transmission to athletes/athletic personnel.

Sexual contact and injection drugs (e.g., anabolic steroids, hormones, vitamins, illicit drugs) present the greatest risk of blood-borne viral pathogen dissemination to athletes. While epidemiologists routinely estimate that transmission of HIV occurs on average once per 1,000 acts of heterosexual intercourse by couples in which only one individual is HIV positive, a recent study has challenged these results. Powers and colleagues found that the estimation of heterosexual infectivity ranges widely, adding that the use of a single value for the heterosexual infectivity of HIV-1 misrepresents important differences associated with transmission cofactors. Additionally, the authors advised that the particular value of one infection per 1,000 contacts between infected and uninfected individuals appears to define a lower boundary, thereby significantly underestimating the infectivity of HIV-1 via heterosexual contact.

Communication of HIV infections among anabolic-androgenic steroid injectors has been well documented in the literature. It should be noted that risk factors other than steroid injecting (e.g., past history of intravenous drug use, needle sharing, imprisonment, number of tattoos received, number of sexual partners) complicate the ability to isolate the risk of steroid injecting for blood-borne pathogen transmission among steroid users. Despite this, steroid-injecting athletes have lower rates of blood-borne infections than intravenous drug users.

While no reports of HIV transmission as a result of blood doping currently exist in the literature, HCV infection as a result of athletes sharing a syringe containing vitamin complexes has been reported.

HIV transmission via body piercing or tattooing remains a potential medical peril, although no published literature currently substantiates this concern. A single case report has documented a possible transmission of HIV-1 during extensive body piercing. No other exposures could be identified in the infected patient. However, as several studies have demonstrated that the presence of body piercings and tattoos may be associated with more risk-taking behavior, caution must be applied when interpreting the significance of such a report.

Hepatitis B Virus

It is estimated that 2 billion people worldwide are infected with HBV; more than 350 million have chronic liver infections. Modes of transmission are identical to HIV, but HBV is 50 to 100 times more infectious, due in part to the virus's stability in the environment (HBV can survive outside the body for more than 7 days) and its high serum concentrations. Infectivity risk estimates, based on occupational exposure data evaluating needle puncture and contaminated–sharp-object injuries, currently place the risk of transmission at 2 to 40 per 100 exposures. The risk of HBV transmission from skin and mucous membrane exposure is generally accepted to be higher than the risk of transmission of other blood-borne pathogens.

While the theoretical transmission rate of HBV during athletic competition has been estimated to be one transmission in every 10,000 to 4.25 million games, numerous documented HBV transmissions have occurred during sports participation. Ringertz and Zetterberg reported an outbreak of HBV infections involving 568 Swedish track-finding (orienteering) athletes from 1957 to 1963. The route of infection was believed to be water contaminated with the blood of HBV-infected athletes, which was used to clean wounds acquired by contact with branches and thorns. In 1980, an asymptomatic high school sumo wrestler in Japan with chronic hepatitis B infection transmitted HBV to his teammates, likely through skin cuts and abrasions. More recently, Tobe and colleagues reported an outbreak of HBV involving 11 athletes on an American football team over a 19-month period (1990–1991). A player with HBV-carrier status (i.e., an individual who harbors and can transmit an infection but is not symptomatic from the infection) was identified as the source of infection; contact with open wounds of the carrier was likely the route of transmission.

Hepatitis C Virus

Worldwide, hepatitis C infections are quite common. Three percent of the global population has been estimated to be infected with HCV. There are nearly 4 million HCV carriers in Europe alone. In the United States, approximately 19,000 new cases of HCV occurred in 2006, the vast majority being asymptomatic and underreported. Nearly 3.2 million Americans have chronic HCV infections. The risk of occupational exposure to HCV is not well established, but the risk of transmission is estimated to be 3 to 10 per 100 exposures through the skin—less than the risk for HBV infection but 10 times greater than that of HIV.

For the athlete, injection drug use represents the primary risk factor for HCV infection. Approximately one third of young (18–30 years old) injection drug users are HCV infected. Additionally, tattooing has been shown in epidemiologic studies to be an independent risk factor for HCV seropositivity. Sexual contact and sharing personal items that are HCV contaminated (e.g., razors, toothbrushes) appear to pose a low risk for HCV transmission.

Case reports involving HCV transmission in weightlifters injecting anabolic-androgenic steroids and soccer players sharing syringes to inject intravenous vitamin complexes have been documented in the literature.

Prevention and Educational Initiatives Involving Blood-Borne Pathogens in Sports

As previously discussed, the primary routes of transmission that place athletes at risk for blood-borne infections are sexual activity and injection drugs rather than on-field sporting activities. It is incumbent on the sports medicine practitioner to educate athletes regarding the detrimental consequences of high-risk behaviors. For many practitioners, the preparticipation physical exam provides an ideal opportunity to counsel athletes on disease transmission issues, dispel myths and misconceptions regarding blood-borne infections, and provide insight and guidance in a nonjudgmental fashion to athletes regarding off-field conduct and risk-taking behaviors.

While the likelihood of on-field transmission of blood-borne infections remains remote, advising the athlete regarding the circumstances in which transmission during athletic activity could occur merits attention. Guidelines addressing preventive measures for reducing blood-borne pathogen transmission in sports have been published by the American Academy of Pediatrics (AAP), the American Medical Society for Sports Medicine (AMSSM), and the American Academy of Sports Medicine (AASM). Since the risk of blood-borne infection in sports is exclusively restricted to contact with blood, body fluids, and other fluids containing blood, the aforementioned guidelines focus on precautions designed to contain bleeding injuries in the context of athletic competition. The following provides a synopsis of the guidelines' recommendations:

- Athletes should be advised that it is their responsibility to report all wounds before or during competition.
- Abrasions, cuts, or oozing wounds that potentially could serve as a source of bleeding or portal of entry for blood-borne pathogens should be covered with an occlusive dressing before and after participation. Caregivers should also cover their own healing wounds to prevent transmission to or from an athlete seeking medical attention.
- Athletes with active bleeding should be removed from participation as soon as possible; bleeding must be controlled, and wounds must be cleansed with soap and water/antiseptic and properly covered before return to competition. Minor cuts or abrasions that are not bleeding do not necessitate stoppage of play; instead, these can be cleansed and covered during breaks in play.
- When managing an acute blood exposure, universal precautions (with the necessary equipment/supplies to implement them) should be practiced by all caregivers. Proper equipment includes latex or vinyl gloves, antiseptic, bleach (1:10 dilution with tap water), alcohol-based disinfectant, receptacles for soiled equipment or uniforms, dressings/bandages, and a "sharps" container for disposal of needles, syringes, or scalpels.
- Equipment and playing surfaces (e.g., wrestling mats) contaminated with blood should be cleaned immediately with disposable towels, then disinfected with a 1:10 bleach solution for at least 30 seconds. The surface should be dry before resuming sports activity.
- Emergency care for life-threatening injuries should not be delayed if gloves or other protective equipment are not available. Breathing (Ambu) bags and oral airways are the preferred equipment for airway management, when available. Mouth-to-mouth resuscitation may be administered when such equipment is not accessible.
- Equipment handlers, laundry personnel, and janitorial staff should be advised to wear gloves when contacting bloody equipment and clothing.

In addition to on-field precautions, sports medicine practitioners should promote HBV immunization among athletes and staff (e.g., coaches, athletic trainers, laundry personnel, janitors). A complete series of HBV vaccine affords vaccinated individuals >95% effectiveness against HBV infection; approximately 5% of HBV vaccine recipients are "nonresponders"—that is, they do not generate an immune response that offers them adequate protection against HBV.

While both the AAP and the American College Health Association have recommended universal hepatitis B vaccine for children, adolescents, and student-athletes since the early 1990s, the sports medicine practitioner should be aware that the increasing reluctance to vaccinate among various parenting communities and subsequent nonmedical vaccine exemptions may affect immunization rates among student-athletes enrolling to their respective institutions.

Role of Testing for Blood-Borne Infections in Sports

The AAP, the AMSSM, and the AASM do not advocate mandatory testing or universal screening of athletes for blood-borne pathogens to determine eligibility for sports participation, citing that such testing "would not effectively prevent infection, promote health, or be easily implemented." The AMSSM and AASM suggest that voluntary testing be offered to athletes and athletic staff who may have potentially been exposed to blood-borne pathogens. Such high-risk individuals would include (1) persons with multiple sexual partners or sexual contacts with at-risk persons; (2) injection drug users (past or present); (3) persons with histories of sexually transmitted infections, including HBV; and (4) persons receiving blood transfusions prior to 1985.

Various organizations involving sports deemed "high risk" for blood-borne pathogen transmission—in particular, the International Boxing Federation and the International Federation of Associated Wrestling Styles—have mandated HIV testing prior to sports participation. Other organizations, such as the International Amateur Boxing Association, only recommend HIV screening as part of their preparticipation physical exams. In the United States, no federal regulations exist pertaining to mandatory HIV screening for boxers. State boxing commissions differ significantly regarding prefight medical requirements, including blood-borne pathogen testing.

Management Issues Involving the Recently Infected Athlete

When implemented, blood-borne pathogen testing should be accompanied by pre- and posttest counseling. In certain cases, such as an athlete with asymptomatic HIV infection, a strategic approach to inform the athlete of (1) his or her infection status, (2) the availability of counseling regarding the psychosocial aspects of the disease, (3) the implications of continued sports participation, and (4) subsequent behavioral modification following infection can be effective as a means of reducing transmission to other susceptible individuals. This can be particularly noteworthy in the setting of the acutely infected athlete, who has a higher risk of transmitting his or her infection via sexual contact due to substantially higher viral loads.

Because infected athletes have a very low probability of infecting other athletes, all athletes with blood-borne pathogens (i.e., HIV, HBV, HCV) should be allowed to participate in all competitive sports. Particular attention has been drawn to boxing and wrestling—sports with the greatest potential for contamination of injured skin by blood. Sports medicine practitioners may choose to encourage infected athletes participating in such high-risk sports to pursue other relatively low-risk sporting activities. Doing so may provide further protection to the infected athlete by minimizing exposure to additional blood-borne pathogens.

Continued participation in sports by the infected athlete is a personal and individual decision. Moderate-intensity exercise has been shown to provide both psychological and immunological benefits to HIV-infected patients, and no evidence exists that intensive training negatively affects asymptomatic HBV carriers. The sports medicine practitioner can play a pivotal role in advising the infected athlete on the decision to continue competing. Referral to an infectious-disease specialist is an essential component of managing the infected athlete; it is particularly important when attempting to determine the individual's state of health and the likelihood of deterioration when exposed to the potentially detrimental psychological and physical stressors that accompany competitive sports.

Athletes acutely infected with blood-borne infections often experience prolonged febrile illnesses accompanied by flulike symptoms. Hospitalization may be required for illnesses such as pharyngitis, diarrhea, and hepatitis/jaundice—conditions typically managed in an outpatient setting in healthy individuals.

Treatments for blood-borne infections may also affect the infected athlete's energy level and/or performance. Interferon, a treatment generally recommended in the setting of HCV to delay the onset of cirrhosis, causes a multitude of side effects, including fatigue, headaches, anxiety, depression, insomnia, and muscle aches—symptom constellations that can make athletic competition extremely difficult.

An athlete who acquires a blood-borne viral infection such as HIV, HBV, or HCV unequivocally undergoes psychological adjustments such as depression during the acute phase of his or her illness that often overshadows every other aspect of his or her life. Sports medicine practitioners need to recognize the challenges athletes face when coping with their illnesses and assist infected athletes with obtaining the proper mental health services necessary to maintain a positive outlook on their futures and to guide them through the inevitable uncertainties they encounter.

Legal and Ethical Considerations Involving the Infected Athlete

When faced with an athlete recently infected with a blood-borne pathogen, it is the responsibility of the sports medicine practitioner to maintain confidentiality about the athlete's infection. With the exception of mandatory reporting to state and public health departments by physicians ordering testing, the athlete and parent/guardian (if the patient is a minor) must give informed consent for medical personnel to disclose information to sports organizations and institutions. It is advised that the sports medicine practitioner familiarize himself or herself with individual states' regulations concerning confidentiality and reporting of blood-borne pathogens. As of April 2008, all 50 states, the District of Columbia, and five dependent areas—American Samoa, Guam, the Northern Mariana Islands, Puerto Rico, and the U.S. Virgin Islands—use the same confidential name-based reporting system to collect HIV and AIDS data.

The legal responsibility to warn fellow athletes and staff members of infection status remains the obligation of the infected athlete, not the physician caring for the infected athlete. While it is understandable that sports medicine practitioners may feel a conflict between keeping an athletes' infection status confidential and informing other athletes/staff members, the AMSSM and AASM position statement is unwaveringly decisive regarding this ethical conundrum: The physician may not disclose the infected athlete's status to other physicians, coaches, trainers, teammates, or opponents.

As previously stated, athletes infected with blood-borne pathogens may not be excluded by an institution or sports organization from athletic participation on the basis of their infection status. Both the Americans with Disabilities Act of 1990 and the Rehabilitation Act of 1973—federal laws applicable to virtually all professional, intercollegiate, and interscholastic sports programs—prohibit discrimination against persons who have physical abnormalities or impairments. Excluding an athlete with a blood-borne infection because his or her physical condition increases the risk of personal harm must be based on "reasonable medical judgments given the state of medical knowledge." Furthermore, the theoretically harmful effects of the prolonged physical exertion inherent to athletic competition on an infected athlete's immune system have not been upheld by the legal system as grounds for exclusion from sports.

Apart from the legal decisions pertaining to participation involving the infected athlete, there are ethical decisions regarding the athlete's state of health. When advising an infected athlete regarding the potential risks and benefits of engaging in sports competition, the sports medicine practitioner, in conjunction with the athlete and the athlete's personal physician, should provide individualized recommendations based on the clinical status of the athlete, the nature and intensity of training and competition inherent to the athlete's sport, and the risk of both transmission and susceptibility of the infected athlete to blood-borne infections in his or her given sport.

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See also Blood Transfusion; Infectious Diseases in Sports Medicine; Legal Aspects of Sports Medicine; Physical Examination and History

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Body Composition (Body Mass Index)

Body composition (body mass index, BMI) is a method used to quantify the percentage of each body component as it constitutes the whole. There are numerous ways to divide the body's components, but the most common method is to divide the body into fat mass and lean body mass (bone, muscle, blood, organs). Alternatively, the body can be divided into water, protein, carbohydrate (glycogen), minerals, and fat. More detailed divisions such as these are most often used for research purposes. Differing body compositions explain why individuals of the same height and weight may still differ in their shape and leanness. Body composition both positively and negatively influences athletic performance in sports and is directly related to many health issues in the general and athletic population.

There are numerous methods for determining an individual's body composition. Methods vary by their reliability, ease of use, cost, and availability. The most frequent method for evaluating body fat is measuring the amount of fat under the skin at various sites using special tools called skin calipers. This method is widely used in health clubs, athletic departments, and medical offices; however, the measurements obtained with this method are the least accurate and are assessor dependent. Another commonly accessible method is measuring the bioelectrical impedance. This method is often used on home digital body weight scales and estimates body fat percentage by calculating the resistance of an electrical current as it flows through the body.

More sophisticated measurements include underwater weighing, air displacement, dual-energy X-ray absorptiometry (DXA), and advanced imaging such as magnetic resonance imaging (MRI) and computed tomography (CT). These more accurate techniques require expensive medical equipment and are commonly reserved for research. Despite the cost, air displacement is becoming more commonly accessible at health and fitness centers as well as sports medicine centers. This method calculates the body's density and body fat percentage by measuring the weight and the amount of air the individual displaces inside the closed unit. The Bod Pod is the most common of air displacement devices found in clinical and research facilities.

BMI is commonly used as a measure of obesity in adults. It is calculated by dividing body weight (in kilograms) by height (in meters) squared. Normal weight is classified by a BMI between 18.5 and 24.9. Individuals classified as overweight have scores between 25 and 29.9, and obesity is defined in individuals with values of 30 and above. Elevated BMI has been linked to multiple medical conditions, including heart disease, diabetes, high cholesterol, and high blood pressure. Unfortunately, while BMI is a fast, easy, inexpensive, and reproducible method, it is not the most reliable measure to evaluate an athlete's body composition. BMI does not directly measure body fat percentage, and thus it can classify a very muscular individual as being obese when in fact he or she may have very little body fat. Therefore, BMI measurements in athletes should be used with caution.

In many sports, performance is directly affected by body size and composition. Scoring in sports such as diving, gymnastics, and competitive cheerleading is subjective and can be affected by the aesthetic build of the competitor. Similarly, sports such as running focus on weight and body composition. Runners may concentrate on losing body weight as a way to increase speed, because many believe that thinner is always faster. Unfortunately, many competitors, especially females, focus on weight loss and unhealthy eating habits, causing hormone imbalances, menstrual irregularities, bone loss, and impaired performance. Other sports, including wrestling, boxing, and weight lifting, use weight classes. For these sports, participants not only focus on weight loss, but also often resort to unhealthy training and dieting methods to decrease their body mass in a short period of time in order to conform to the prescribed weight classes for competition.

There are also sports that center on gaining weight, both lean mass and fat mass. Training and eating to produce mass is undesirable in most sports but can be advantageous for sports such as sumo wrestling and American football (linemen). These individuals do put themselves at risk of developing the same medical complications of overweight and obese individuals as described earlier. Counseling athletes to focus on maximizing lean mass rather than fat mass and counseling them about healthy modifications once their athletic careers are completed are vital. As we have described, body composition is often a focus of athletes, coaches, and their medical professionals, and there are many reasons for altering one's body composition. The constant drive for athletes to reach their ultimate potential often leads them to extreme measures to reach the "ideal" body type or body composition for their sport/position.

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See also Fitness Testing; Lean Body Weight Assessment; Menstrual Irregularities; Obesity; Weight Gain for Sports; Weight Loss for Sports

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Bowel Injury

Bowel injury is infrequent in sports and most commonly occurs as a result of a forceful blow to a small area over the small intestine. Injury can also result from lack of blood supply, but such acircumstance seems to have some genetic predisposition accompanied by vigorous endurance exercise.

Bowel Injury Resulting From Abdominal Trauma

Epidemiology

Traumatic injuries to the bowel are more common in contact sports (e.g., soccer, rugby, football), sports involving high velocity (e.g., skiing), and sports with a high frequency of falls (e.g., equestrian). Blunt abdominal trauma causing jejunal rupture has been described following a punch to the abdomen as well as following blunt trauma to the abdomen. Perforation of the gastrointestinal tract is reported in 4% to 9% of patients who present at hospital with blunt abdominal trauma. While most of these injuries are a result of motor vehicle accidents, bicycle handlebar injuries have been reported to account for 14% to 20% of the cases. Cases of duodenal rupture following sport-related blunt injury have been described during cycling, hockey, skating, soccer, and American football. Three cases of jejunal rupture during participation in American football and soccer have been reported so far.

Anatomy and Pathophysiology

The abdomen is relatively poorly protected, with superficial rectus abdominus and transverse abdominus muscles providing some limited coverage. When a direct blow lands on a small area of abdomen, enough force to eviscerate the bowel can be transferred. Such an event can occur when a bicycle handlebar is spun 90° and jabs someone in the epigastric region, resulting in duodenal injury (see photos, next page).

The mechanism of bowel rupture is variable and controversial. Direct compression with tearing between two opposing surfaces, such as the abdominal wall and spine, is thought to be the most likely cause of bowel injury. Fixed areas of the bowel, such as the duodenum, proximal jejunum, terminal ileum, or areas with adhesions are at increased risk.

Bicycle handlebar trauma to epigastric region of the abdomen

Source: Courtesy of David Mooney, M.D., Children's Hospital Boston.

Clinical Presentation

Athletes with abdominal trauma usually complain of abdominal pain. It may be important to determine how quickly the pain develops, whether it is local or diffuse, and if it progresses to involve the entire abdomen. Injury to the abdominal wall usually produces local pain, whereas injury to the internal organs such as the bowel often initially causes localized pain that may spread to the entire abdomen if intraperitoneal irritation develops.

Physical findings may be limited, despite the propensity for life-threatening injury, hence a high index of suspicion for bowel injury is necessary. Abdominal guarding, rigidity, rebound tenderness, and pain with laughing, coughing, jumping, or bouncing are other signs of intraperitoneal irritation. Radiation of pain to the left shoulder (Kehr sign) due to blood irritating the diaphragm is called the Cullen sign, a bluish periumbilical discoloration suggesting hemoperitoneum, and it may be present. Signs of injury may develop over time, requiring serial examination to elucidate.

Persistent abdominal pain should alert the practitioner to other symptoms of chemical or bacterial peritonitis, including fever, nausea, and vomiting. In addition to the tenderness and guarding noted above, loss of bowel sounds on auscultation can be a sensitive (though certainly not specific) finding for injury to the bowel. Diagnosis of peritonitis due to bowel perforation is often delayed because there is usually no associated major blood loss. The small intestine is the most common site of such perforation, and peritonism may not be evident initially because the content of the small bowel is of a neutral pH, low bacterial density, and low enzymatic activity. Studies have reported that only 38% to 54% of cases had signs of peritonism at presentation.

Evaluation

If an injury to the bowel is suspected, athletes should not be allowed to continue participation and should be transported immediately to a facility with hemodynamic monitoring and imaging capability. In transit, signs of cardiovascular shock might become apparent, necessitating fluid resuscitation with intravenous access.

Once in a suitable setting such as an Emergency Room, erect chest X-ray may reveal air beneath the diaphragm, although computed tomography (CT) is the most sensitive diagnostic imaging method. A plain radiograph is also unreliable in the diagnosis of bowel perforation as there is no pneumoperitoneum in 54% to 85% of cases. The small bowel contains little air, unlike the stomach or colon, in which perforation more frequently results in appreciable pneumoperitoneum.

Patients with significant blunt abdominal trauma should have baseline hematological and biochemical laboratory tests performed, including a complete blood count and determination of serum electrolytes, glucose, amylase, and, in the female athlete, human chorionogonadotrophic hormone to determine pregnancy.

Patients are triaged based on their hemodynamic status. As is the case with the solid abdominal organs, diagnostic peritoneal lavage (DPL) and laparotomy are indicated in hemodynamically unstable patients suspected of having an injury to the bowel. Nasogastric tube placement may be helpful to check for blood in the stomach.

With the increasing availability of bedside ultrasonography and rapid access to CT, a decrease in the frequency of DPL use has been noted. Ultrasonography has been shown to have equal sensitivity and specificity to DPL in diagnosing intraperitoneal free fluid. Ultrasonography has the added advantage of being a virtually dynamic investigation and can be repeated at frequent intervals. Its sensitivity for identifying intestinal injuries is lesser, however, than for detecting splenic or liver injury.

Unfortunately, laparotomy is often required to make an accurate diagnosis and definitively treat individuals with injury to the stomach and intestine.

Differential Diagnosis With Abdominal Trauma

A less severe abdominal blow more commonly results in the "wind being knocked out" of an athlete. In this case, mild trauma irritates abdominal musculature such as the diaphragm, inducing a brief period of dyspnea, which resolves with loosening of restrictive clothing and hip flexion for a few minutes.

Bowel Injury Resulting From Endurance Activities

Epidemiology

Estimates of the incidence of blood passed per rectum, indirectly indicating bowel injury after a marathon race, range from 8% to 85%. With longer distances, such as in ultramarathon events, the incidence increases. Sixteen percent of runners in one study reported having bloody diarrhea on at least one occasion after a race or hard run, and 30% to 81% reported gastrointestinal (GI) complaints during long runs and races.

Pathophysiology

With exercise, blood flow is preferentially redirected to the working skeletal muscle, and flow to the GI tract can be reduced by as much as 80%. This relative ischemia can compromise gut function on a spectrum from mild cases, manifested by commonly experienced GI symptoms such as cramping, to severe cases of ischemic colitis. With aerobic training, this decrease in blood flow becomes less, although it does not reliably predict which runners will become symptomatic. There is no clear evidence that less fit individuals are more prone to symptomatic ischemia.

Nonsteroidal anti-inflammatory drug (NSAID) use has been associated with GI bleeding in athletes and may increase the incidence of GI complaints.

An alternative theory to explain a GI injury is that it results from repetitive mechanical microtrauma suffered by the gut from the impact of foot strike while running during gait cycle activity.

Presentation

Athletes can present to the medical tent after a race with bloating, cramps, nausea, vomiting, diarrhea, and fecal incontinence from running. Relevant history questions particular to an event include prior episodes of GI complaints with activity, as well as the timing of symptoms. Performance indicators, such as finish time compared with previous marathon race attempts, will give an idea of the level of exertion during the race. Environmental factors, as well as the amount of fluid ingested, should be taken into consideration because dehydration exacerbates the low-flow state and increases GI complaints.

The presence of bloody bowel movements after an endurance event should raise the possibility of ischemic colitis.

Evaluation

Fluid resuscitation is the first priority in the acute management of suspected endurance event–induced bowel injury. Cardiovascular volume status should be estimated from blood pressure and heart rate; body weight is probably the most accurate predictor of fluid loss if a pre-event weight is available. Transfer of any athlete with bleeding per rectum to a tertiary care facility is warranted. A colonoscopy can be undertaken once the patient has been stabilized.

Prevention

The use of cimetidine before and during a race has been shown to reduce the incidence of bloody stools afterward. The use of NSAIDs before endurance events should also be discouraged.

Hamish A. Kerr

See also Abdominal Injuries; Football, Injuries in; Horse Riding, Injuries in; Skiing, Injuries in

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Bowlegs (Genu Varum)

Genu varum (bowlegs) is an angular deformity of the knees. It is common for young children and younger athletes to be sent to an orthopedist for evaluation, but most patients are within the normal limits. Although most bowlegs will resolve on their own, it is important to identify patients outside the normal limits who may need further evaluation. It is also important to give families reassurance about patients within normal limits (see Figure 1).

Figure 1 Bowlegs (Genu Varum)

Note: Athletes with bowlegs are at greater risk of sustaining problems on the outer side of the knee. However, many athletes with bowlegs participate in distance running without such problems.

Normal Development of the Legs

While developing, the fetus is usually positioned with hips and knees flexed in the uterus. The feet and tibia can be internally rotated (pointed in). This positioning causes a tightening of the medial ligaments of the knee, leading to bowlegs at birth. The bowlegged position at birth is normally the maximum for a person.

As the child begins to walk and grow, the ligament tightening begins to stretch, allowing the knees to straighten out. Between 18 and 22 months, the angular deformity begins to correct, and the legs will appear straight.

This straightening will continue over the next 3 years and actually lead to an overcorrection, causing genu valgum (knock-knees). This is usually most evident at about 4 years of age. As the child continues to age and grow, the genu valgum begins to correct. By about 7 years of age and into adulthood, most people will retain a slight valgus deformity of about 5° to 8°.

Clinical Evaluation

History

One of the most important things to consider is the patient's age. It has been noted that the persistence of bowlegs beyond 2 years of age is likely to be abnormal. It is important to identify whether the deformity worsens as the child grows. Reviewing old photographs of the child's legs will be helpful in the evaluation. Pain is an uncommon complaint.

Dietary history can reveal important information about nutritional deficiency being a potential cause. Family history, specifically for Blount disease, and past medical history should also be reviewed.

Physical Exam

A physical exam should begin with plotting overall height, as short stature is common with rickets and skeletal dysplasia. It is important to identify if the bowing is on both sides or is unilateral. In most cases, asymmetric bowing indicates abnormality.

With the patella facing forward, measure the angle of the knee. Measuring the intercondylar distance (between the two medial femoral condyles) and intermalleolar distance (between the two medial malleoli) can provide objective information to assess the deformity. All these measurements can be plotted on charts to help identify normal versus abnormal angular deformities.

The child may need to return every 3 to 6 months for repeat measurements in order to ensure that the deformity is not worsening. It is important to take the measurements in the same posture (lying down or standing) each time for consistency.

Radiographs

Ideally, X-rays should be taken in the standing position with kneecaps facing forward. If the feet are facing forward instead of the kneecaps, it can exaggerate the appearance of the bowlegs. X-rays should cover the region from the hips to the ankles.

X-rays should be obtained for children with bowlegs who are above 2 years of age or for children with pain, severe deformity, or unilateral bowing.

Diagnosis and Treatment

Physiologic Bowlegs

Physiologic bowlegs are symmetric bowing seen in children below the age of 2 years. Parents will usually report that the condition improves as the child grows. The patient will generally have a normal height and normal screening measurements. The family should be reassured, and the measurements should be taken every 3 to 6 months if needed.

Blount Disease

Blount disease, also known as tibia vara, is a disorder that causes irregularity at the growth plate of the medial, proximal tibia. The cause is unknown, but it appears to be related to damage from mechanical stress to the growth plate. The risk factors are positive family history, African American origin, and obesity. The clinician should be highly suspicious of Blount disease in children who have unilateral deformities and are early walkers.

Early or infantile Blount disease usually occurs in obese, female African Americans younger than 3 years old. Adolescent Blount disease occurs more often in obese, male African Americans older than 8 years of age. Many patients will describe a history of bowlegs that never improved and rapidly worsened during a growth spurt. X-rays show abnormalities of the medial proximal tibia.

Treatment of Blount disease requires prompt recognition and referral to an orthopedist. Bracing may help in patients younger than 3 years of age who have mild Blount disease. If the disease is severe or the patient is nonresponsive to bracing, the surgeon may perform a proximal tibial osteotomy (removal of a wedge of bone). In adolescent Blount disease, the surgeon may consider stapling or a hemiepiphysiodesis, too.

The prognosis of Blount disease depends on severity. Younger children may have recurrence as they age through childhood. If the deformity is not fully corrected, it can lead to degenerative arthritis.

Other Causes

Rickets is a nutritional deficiency that can cause bowlegs. This disorder is described in the entry Knock-Knees (Genu Valgum).

Focal fibrocartilage dysplasia is an unusual cause of unilateral genu varum that usually resolves with conservative treatment. This is a small bony defect at the medial tibial metaphysics (just under the growth plate). However, if it does not resolve, surgical intervention is necessary.

Achondroplasia is a genetic condition more commonly known as *dwarfism*. The genu varum in this case is caused by abnormal bone growth. This usually will not improve with bracing and requires surgery.

Kevin D. Walter

See also Calcium in the Athlete's Diet; Dietary Supplements and Vitamins; Femoral Anteversion (Turned-In Hips); Knock-Knees (Genu Valgum)

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Boxing, Injuries in

All contact sporting events carry a risk of injury. Of all sporting events, boxing ranks first in the potential for injury, with 5.2 injuries per 1,000 athlete exposures. Although amateur and professional boxing activities appear similar, they differ in scoring and types of injuries.

In amateur boxing, injuries are fewer and less severe because amateur boxers are required to wear more padding, along with protective headgear. Additionally, amateur boxing is scored differently than professional boxing. In amateur events, points are scored on skillful punches, with less emphasis given for the knockout.

As amateur boxers wear more padding, have protective headgear, and fight fewer rounds, it is the professional boxers who have the higher risk for injury. Science has determined that the force of a professional boxer's punch is equivalent to being struck with a 13-pound bowling ball traveling at 20 miles per hour.

Many health professionals and organizations have concerns about the safety of the sport, especially the trauma to the brain. Although boxing ranks high as a dangerous sport, the death rate is actually lower than for some other sports. However, the long-term effects of boxing suggest that 15% to 40% of professional boxers exhibit evidence of brain injury that includes memory loss, unsteadiness, speech difficulties, and increased stiffness as a consequence of cumulative head trauma.

Head and Face Injuries

Excluding minor injuries, head and brain injuries are the most common for the boxer. The most common of these are brain *concussions*. Concussions are transient alterations of brain function, with or without loss of consciousness, that resolve without evidence of any permanent brain damage. Concussions differ in severity based on the duration of unconsciousness and the degree of amnesia or memory lapse.

Brain injuries in boxing are divided into two major types: acute immediate injury and chronic, where the injury develops over a period of time. Acute brain injury is more severe and life threatening when it results from a ruptured brain blood vessel due to a boxer's punch to the head. This ruptured brain blood vessel spills blood within the brain cavity, resulting in increased pressure that pushes on vital centers of brain function. The repetitive and cumulative effects of taking punches to the head result in chronic head injury, commonly referred to as "punch drunkenness." Symptoms of punch drunkenness include inhibited thinking ability, headaches, and blurred vision or memory loss.

Punches to the face and head can result in injuries to the eyes, nose, facial bones, and jaw. Most injuries occur from the glove impact and result in regional contusions on the face and head. The more serious facial injuries occur from the gloved knuckle or thumb. Eye injuries hold the highest risk of permanent injury and may be career ending. A strong punch to the eye may detach the retina and require surgical repair. Other ocular boxing injuries include corneal abrasions, orbital blowout fractures, and intraocular bleeding.

Facial lacerations and facial bone fractures are a common injury resulting from a punch or head butt. These lacerations are usually minor, with the exception of an upper eyelid laceration. An upper lid laceration should be evaluated for underlying damage to the forehead bone along the tarsal plate, and if a fracture is suspected, this clinical situation requires immediate medical intervention.

Injuries to the nose include fractures of the nasal bones and damage to the nasal septum cartilage. Septal deviation may cause obstruction of the nasal passages and impede breathing. Surgery may be required to open the nasal passages.

On rare occasions, the mandible or jawbone may be broken with a strong punch. Suspected fractures require immediate medical evaluation and may necessitate surgical stabilization. Broken teeth are the most common dental injury.

Ribs and Abdomen Injuries

Rib injuries are fairly common. Besides being quite painful, a broken or fractured rib may be very dangerous in that it may pierce the lung, causing it to collapse. Just below the lower ribs, the spleen is vulnerable and could rupture from a forceful punch. Ruptured spleens often require surgical removal as they can cause extensive internal bleeding, resulting in quick death. Liver bruising and kidney bruising may occur but rarely require any surgical intervention.

Upper Extremity Injuries

The shoulders, upper arms, forearms, and wrists are sites of frequent injury for the boxer during training inside and outside the ring. The most common of these are hand injuries. The "boxer's fracture" is a fracture at the base of the little finger. Most of these boxer's fractures can be treated without surgery by first aligning the bones and then applying an immobilizing splint. If alignment cannot be corrected, then surgical correction may be required.

Fracture of the long bones of the ring and middle fingers, the metacarpals, is more serious with regard to reestablishing alignment. If the alignment of these bones is not adequately achieved, surgical pinning should be considered. Boxers can sustain serious hand and knuckle injuries by throwing an awkward punch causing injury to the knuckle, commonly called a "boxer's knuckle." A boxer's knuckle results in a tear to the protective sheath of the extensor tendon overlying each knuckle, most often involving the index and the middle fingers. Typically, pain is the complaint in the area of the tear overlying the affected knuckle. Examination will reveal weakness when attempting to extend the affected finger, and palpation may identify a depression within the extensor hood. Tendon tears necessitate surgical repair followed by casting the wrist and hand for 6 weeks. After the cast is removed, rehabilitation must provide full range of motion and muscle strength before the boxer is allowed to punch.

Studies and Statistics

The U.S. Olympic Training Center in Colorado Springs, Colorado, collected and analyzed records of amateur boxing injuries from 1977 through 1992. This study found that only a relatively small percentage (6.1%) of these injuries were classified as serious. The breakdown of the frequency of injuries found that upper extremity injuries were the most frequent at 25%, followed by head and facial injuries representing 19%. Lower extremities accounted for 15%, with spinal injuries representing 9% of all injuries. This study found that contusions represented 24.9%; muscle strains, 20.8%; joint sprains, 17.5%; concussions, 6.1%; and fractures, 4.9%.

Another amateur boxing study reported that 48% of all competition injuries were the result of a punch to the head. An 8-year study of instructional boxing in the U.S. Marine Corps basic training found that within a group of 180,000 participants only three sustained serious acute brain injuries, constituting an extremely small proportion (0.3%) of the approximately 1,000 boxing-related injuries that occurred during the survey period. This study may underrepresent the true incidence rates, as those events were largely noncompetitive and involved more sparring and training rather than the actual matches.

Boxing Injuries and Death

Accurate evaluation of boxing-related deaths is difficult. Differences in the regulations of amateur and professional boxing, poor reporting of worldwide boxing-related injuries and deaths, illegal boxing events, and lack of medical data contribute to poor statistical analysis. Recent U.S. statistics on sports-related deaths found boxing to rate eighth overall in incidence rates. Horse racing was the highest at 128 fatalities per 100,000 participants, followed by skydiving at 123, hang gliding at 55, mountaineering at 51, scuba diving at 11, motorcycle racing at 7, college football at 3, and boxing at 1.3.

Professional Boxing Injuries

There are relatively few boxing studies and even fewer in professional boxing. A study of professional boxing event injuries was done over a 2-year period from 2001 to 2003 in Nevada. The study found an injury rate of 17.1 per 100 boxer matches. The breakdown of injuries found facial lacerations accounting for 51% of all injuries, followed by 17% hand injuries, 14% eye injuries, and 5% nose injuries. Male boxers were three times more likely to sustain injuries than female boxers in this study. Boxers who lost by knockouts or technical knockouts doubled their risk of injury when compared with their winning opponent. Weight and age were not factors in predicting the risk of injury.

Long-Term Injury in Boxing

Concern over the medical consequences of long-term head trauma creates controversy over the safety of the sport. The American Medical Association (AMA) takes a strong position, opposing all forms of boxing. The AMA recommends the prohibition of all forms of boxing for people below the age of 18 years. To improve the safety of boxing and minimize the risk of injury, the AMA provides recommendations that most state boxing commissions have incorporated into their licensing and regulations.

Unlike many other contact sports, head injuries in boxing are not accidental. Although amateur boxing mandates protective headgear to minimize brain trauma, clinical studies have found evidence that participation in amateur boxing matches can diminish neurocognitive functioning. On the other hand, professional boxers, who do not use protective headgear, sustain multiple head blows resulting in cumulative head injury. A limited study of 42 professional boxing volunteers evaluated multiple neurocognitive variables to assess the degree of brain injury. The results identified that the amount of sparring by the boxers was an important factor in the decline of neurocognitive performance. The study found neurocognitive impairments in areas of attention, concentration, and memory. Interestingly, performance on the neuropsychological tests showed no association with the professional boxer's age, boxing record (wins, losses, or total number of bouts), length of career, or history of knockout or technical knockout.

"Punch drunk syndrome," or dementia pugilistica, is a medical condition caused by repeated brain trauma, such as in boxing. The symptoms include dementia, memory loss, confusion, psychosis, and abnormal movement, similar to the symptoms seen in Alzheimer disease. The risk of a boxer developing this condition correlates with the number of matches and the length of the boxer's career. This condition affects 17% of professional boxers.

Consequently, older boxers are more vulnerable to diseases of the brain and progression of aging of the brain. Alzheimer-like dementias and Parkinsonian diseases are the more common presentations and are more prevalent among former boxers than within the age-matched population. Diagnostic imaging reveals a greater degree of changes in the brain, showing a thinner surface gray matter, a decrease in the brain's white matter, and enlarged brain ventricles.

Boxing is one of the oldest sports. Unfortunately, little has been done to identify and track injuries in training and events. Better data collection systems should be mandated to assess the actual risk of injury for both amateur and professional boxers. Based on clinical data, changes related to safe participation can be instituted.

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See also Concussion; Head Injuries; Punch Drunk Syndrome

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Bracing

The use of braces as a support for joints while an athlete is participating in sports has been a very common and well-established practice during the past 30 to 40 years. Today, bracing has grown into a large industry in the United States. However, there is conflicting evidence as to the effectiveness of braces in sports activity.

Bracing is thought to influence the efficacy and performance of a joint in multiple ways. It is widely thought that there are structural benefits in bracing a joint. These benefits include limiting the range of motion of a joint; this becomes important particularly when forces applied to a joint may cause the joint to exceed its normal range of motion, thereby creating the potential for injury. It is also thought that a brace, in the face of an injury force, may help dissipate and limit the force applied to the joint. Finally, it is thought that bracing may provide some benefit by limiting the ground reaction forces that are applied to a joint during sports activities.

There is also evidence for other types of benefits from braces. It is widely accepted that braces can affect the kinesthesia of a joint, or the sensation of muscle movement that one experiences during sports activity. It is thought that this, coupled with the proprioceptive benefit that braces provide, leads to an increased sense of joint position and function, thereby leading to increased performance. There is evidence that braces also affect the neuromuscular responses of the muscle groups that are affected by a brace; studies have shown that muscle groups may have decreased strength of contraction as well as a slowed response with bracing.

These neuromuscular responses highlight one of the difficulties in determining the effectiveness of braces as a class. In some instances (e.g., injury), it is advantageous for an athlete to have decreased contraction of muscles and increased periods of muscle rest. However, in the case of athletes trying to perform at their peak, this would not be a desired side effect of a brace. Research into the neuromuscular response of muscles with both acute and chronic brace use has been common over the past two decades; however, there have been conflicting results, making it unclear whether the use of braces is beneficial or harmful with regard to athletic performance.

In fact, research on the use of braces has its own limitations. In general, most research that is done with bracing involves the use of cadavers rather than live subjects. This type of research is often used to show the restriction in the range of motion of a joint while using a brace; however, cadaveric tissue does not respond in the same way as a live tissue would, as there are, among other problems, changes in the skin, in the muscles themselves, and, most important, in the neuromuscular response. However, there are also difficulties in using live subjects. These include the difficulties in finding an effective placebo for a brace, as well as the difficulties in standardizing brace-fitting as well as research protocols.

There are multiple types of braces available today. However, these types can be divided into three main categories to describe their use in sports: (1) prophylactic, (2) functional, and (3) rehabilitative (postsurgical). Prophylactic braces are those applied prior to injury to attempt to limit the number of injuries suffered during participation in sports. The use of braces to prevent injury has been common in some sports, such as the use of ankle braces in basketball and volleyball and the use of knee braces in football. Here, the use of braces has been a supplement to the use of taping for the same purposes. In many ways, bracing may be more cost-effective than taping, particularly when the salaries and time of those who apply the taping is figured into the total cost. There has been some research done in this field to support the use of such braces as prophylaxis, particularly in jumping sports such as basketball and volleyball. There is some limited research to support the use of knee braces by football players, but their effectiveness seems to be limited by the position played (braces may be effective for offensive linemen but not for wide receivers). There is also evidence that braces may be effective in preventing some types of injuries while not preventing others (prophylactic braces appear to limit the number of medial collateral ligament [MCL] injuries in offensive linemen while not changing the rate of anterior cruciate ligament [ACL] tears).

Functional braces are a very broad category, as almost all braces are desired to be “functional.” In general terms, these are used to provide support to a joint or body area that has suffered some sort of injury. These braces, along with prophylactic braces, can be prefabricated and obtained over the counter. These can also be custom made to the desired fit of an athlete.

Elbow braces are frequently used by racquet sport players.

Source: Julian Rovagnati/iStockphoto.

Rehabilitative braces are very commonly used, particularly following surgical repair of injuries. The use of braces such as this allow athletes to return to sports earlier while providing the support required for participation. There has been a fair amount of data published to support the use of braces in a rehabilitative phase, which would fit well with our current ideas about injury and rehabilitation. On most occasions, these braces are custom made to fit the needs of the patient.

In spite of all the aforementioned difficulties, braces are widely used in sports. Athletes will often use any item that they believe will provide them with a competitive advantage, either in performance enhancement or in injury prevention. The most commonly used braces are those for the lower extremity, particularly for the knees and ankles. In general, upper extremity braces are more difficult to use and apply and are typically not as comfortable for use in sports. Braces are also used in general sports medicine practice as well as for a variety of conditions. Some of these include carpal tunnel (cock-up wrist braces), lateral epicondylitis (tennis elbow strap), patellar tendinosis (patellar tendon strap), and chondromalacia patella (patellar tracking brace). While there is not much research that supports their use in sports, athletes will continue to make use of any devices available that they believe will enhance their performance and enjoyment of the game.

Daniel S. Lewis

See also Knee Bracing; Principles of Rehabilitation and Physical Therapy; Protective Equipment in Sports; Strains, Muscle; Taping

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British Association of Sport and Exercise Medicine

The British Association of Sport and Exercise Medicine (BASEM) was founded in 1953 by a group of doctors, sports scientists, and those from allied disciplines who were involved in the care of individuals and teams in international sports. Their initial objectives, which have remained largely unchanged since that time, were to represent the professional needs of those doctors working in the specialty of Sport and Exercise Medicine (SEM), to advise on career structures, and to provide support and education for those health care professionals involved in the care of athletes and individuals undertaking, or aspiring to undertake, regular physical activity at all levels. They promoted the adoption of evidence-based practice in all areas of SEM and hoped to encourage the highest standards of clinical practice in the care of the exercising individual.

Meeting in London, the founders gained charitable status for the organization and produced guiding rules, "The Articles and Memorandum of Association," which are regularly updated (available at the association's website: http://www.basem.co.uk). The aims are to support and encourage research in SEM and to promote the adoption of exercise and physical activity by all sections of the population for their general well-being and for the prevention and treatment of illness.

The founding members agreed to assist and advise all relevant authorities to adopt policies that encourage and promote physical activity in schools, the workplace, and the home, and to collaborate with other associations, both nationally and internationally, in furthering the specialty of SEM and the aims of BASEM.

The pioneers' first conference in 1962 was held at Loughborough University, and early figures involved included Arthur (later Lord) Porritt, John Williams, and Henry Robson. Later in the decade, they introduced the *British Journal of Sport and Exercise Medicine*. Since 1996, this has been jointly owned with the British Medical Association. Produced monthly, it now has the highest impact factor of any sports medicine journal in the world. (A complete set of BASEM journals is available for study through the library of the University of Bath.)

The BASEM provides the medical practitioners for all elite sports teams within the United Kingdom and has close links with the British Olympic and Commonwealth Games Associations.

With the foundation of the British Association of Sport and Exercise Sciences (BASES) in the 1980s, the membership of more than 1,000 members became increasingly medically orientated, and in 2004, the BASEM was voted to become a doctor-only organization. This allowed it to re-amalgamate with the U.K. Association of Doctors in Sport (UKADIS), which had broken away from the parent organization in 1997.

The campaign by BASEM for professional recognition in the United Kingdom took a giant step forward in 2005 with the formation of a Faculty of Sport and Exercise Medicine under the auspices of the Royal College of Surgeons in Edinburgh.

The association holds an annual Congress, to which the leading researchers and specialists are invited to speak, and since 2004, a Spring Meeting, which is more cutting-edge. There are other training courses for aspiring SEM doctors. Details of the activities and membership of the association are available on the organization's website.

Patrick John Murray Milroy

See also American College of Sports Medicine; American Medical Society for Sports Medicine; American Orthopaedic Society for Sports Medicine; American Osteopathic Academy of Sports Medicine; International Federation of Sports Medicine

Websites

The British Association of Sport and Exercise Medicine: http://www.basem.co.uk

British Journal of Sports Medicine: http://bjsm.bmj.com/site/about

Bruised Foot

A *bruise,* or contusion, of the foot is a common sports injury caused when blood vessels are damaged or broken as a result of a blow to the skin. This injury can be caused by a high-impact direct blow or from lower-impact repetitive forces. Contusions can affect the skin, muscle, and even bone in higher-impact injuries. Most contusions heal quickly without any interference in sports activity; however, more severe contusions can take longer to heal and keep the athlete sidelined for several months.

Diagnosis

History

The diagnosis of a bruised foot should begin with the history of the injury. The athlete may relate sudden onset with a blunt force trauma, such as the foot getting stepped on or kicked during a contact sport. Alternatively, the athlete may relate a slow and gradual onset with chronic repetitive stress to a specific area, such as the ball of the foot during running.

Physical Examination

Next, the physical examination of the foot should be performed. Physical examination may demonstrate purplish or bluish discoloration, and swelling may be evident. The purple discoloration is due to leaking of blood from disrupted blood vessels into the skin. In more severe cases, a lump may be felt in the injured area. This is called a hematoma and is the result of a pool of blood collecting under the skin.

Palpation of the bruised area tends to be painful, and a gentle touch should be used to prevent further injury to the disrupted blood vessels. Passive and active range of motion of the adjacent joints should be attempted to rule out fractures, muscle rupture, and tendon injuries.

In the foot, the most common areas of increased pressure with athletic activity include the heel and the ball of the foot. In particular, pain under the ball of the foot is commonly called a "stone bruise," or metatarsalgia. This is occasionally accompanied by swelling and is the result of chronic repetitive stress.

Imaging Studies

Radiographs

The bruised foot is largely a soft tissue injury. However, if the history of the injury or physical examination suggests the possibility of a fracture in addition to the contusion, plain radiographs of the foot should be taken.

Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is rapidly becoming the imaging modality of choice with soft tissue injuries. In the bruised foot, an MRI scan should be ordered only when there is concern with stress or occult fractures or when the symptoms are not responding to treatment.

Because of its ability to evaluate edema, or swelling, in the deeper tissues, MRI can be useful in detecting bone bruises. Bone bruises result from trabecular microfractures, causing increased fluid changes on the MRI scan.

Treatment

Initial Treatment

Initial treatment of the bruised foot consists of the RICE (*r*est, *i*ce, *c*ompression, *e*levation) formula:

Rest: The injured area should be protected from further trauma. Depending on the severity of the contusion, the athlete may need to stop participating in sports or is even placed on crutches.

Ice: The contusion should be iced to decrease the inflammation that accompanies the injury.

Compression: The injured foot should be placed in a compressive-type dressing, such as an elasticized wrap. The elastic bandage should be applied starting from the toes and gently advanced toward the ankle and up the lower leg to move the swelling up toward the torso.

Elevation: The affected foot should be elevated above the level of the heart to assist in decreasing the swelling.

The pain from the contusion is usually treated with over-the-counter or prescription-strength nonsteroidal anti-inflammatory drugs (NSAIDs). These medications also help decrease the swelling and inflammation associated with the contusion.

Occasionally, a large hematoma will not resolve on its own and will cause persistent pain symptoms. In these instances, it may be necessary for the hematoma to be drained with a simple procedure.

Return to Sports

An athlete may return to sports once the pain symptoms resolve and the strength and motion to the foot have returned. Depending on the nature of the injury, supportive foot devices called orthotics or special padding may be used to prevent recurrence of the bruised foot.

Thanh Dinh

See also Contusions (Bruises); Foot Injuries; Orthotics

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Bruised Ribs

Ribs serve as the key protector for the vital organs in the torso. The human body has 12 ribs on each side, which are divided into different categories based on their function during the motions of inspiration and expiration (inhaling and exhaling). Ribs 1 through 5 typically function in a pump-handle motion. Ribs 6 through 10 function in a bucket-handle motion. Finally, Ribs 11 and 12 typically move in a caliper motion. Furthermore, ribs are defined and divided by their means of attachment to the torso. Ribs 1 through 7 are deemed "true" ribs as they directly connect to the sternum (breastbone) via cartilage (costochondral area). Ribs 8 through 10 are called "false" ribs as they do not directly connect to the sternum and only connect to the cartilage. Ribs 11 and 12 are called "floating" ribs as they do not connect to the sternum or cartilage. Understanding these terms is important to diagnose and treat bruised ribs. When injured, ribs may be strained, broken, bruised, separated, locked down, or locked up. The small intercostal muscles surrounding the ribs may take substantial time to return to normal. Quick diagnosis and treatment lead to quicker return to play.

Mechanism of Injury

An injury typically occurs with a direct blow to the ribs or the cartilage. Broken ribs commonly occur as a fracture of the bony prominence in the middle of the rib, which is normally in the midaxillary line (the area directly below the armpit). Costochondral separation describes an injury that divides the ribs from the cartilage and can occur from landing hard on the feet or even a forceful sneeze or cough. Bruised ribs indicate an injury to the bones, intercostal muscles, or cartilage.

Symptoms

An athlete develops pain directly over the rib or in the area in between the ribs. Pain can also occur with a deep inspiration, hard cough, or sharp movement. In addition, sudden shortness of breath could indicate a rib fracture that could have punctured a lung.

Diagnosis

The sports medicine physician can perform a physical exam, including auscultation (listening to the lungs), percussion (tapping on the lungs), palpation (touching the ribs), and examination of the entire length of the ribs. Ecchymosis (bruising) near the site of injury can provide a clue in the diagnosis. A chest X-ray may be ordered to confirm the diagnosis or to evaluate more complex cases.

Treatment

Treatment of bruised ribs depends on the type of injury. First and foremost, patients should rest. Ice, nature's anti-inflammatory, should be applied intermittently for 20 minutes at a time throughout the day. Nonsteroidal anti-inflammatory drugs, such as ibuprofen or naproxen sodium, may help over the first 10 days of the injury. A sports medicine physician may recommend a rib belt for compression to decrease the symptoms. The rib belt's compression decreases the movement of the injured rib, allowing the intercostal musculature to heal.

Additional therapy may include osteopathic manipulative therapy (OMT), especially if an athlete presents with a locked-down or locked-up rib. Ribs become "locked" when there is a spasm of the surrounding rib intercostal muscles, thus preventing the rib from moving up during inspiration. A sports medicine physician may perform various osteopathic manipulative techniques, such as the high-velocity, low-amplitude technique, underneath the rib that is locked down to break the spasm. A myofascial release (the area between the muscle and the bone) is then performed passively with direct palpation in between the rib muscles to decrease the local rib spasm. The patient would then continue applying ice and taking anti-inflammatory medicine as previously stated.

Return to Sports

Return to sports depends on multiple variables. First, return to play is based on the type of rib injury. A broken rib injury typically takes 4 to 6 weeks to heal completely, thus allowing the athlete to safely return to play. A repeat X-ray may be required prior to clearance for return to play. Occasionally, if there is evidence of healing, the athlete may return sooner with protection over the affected area. Return to play with bruised ribs or a costochondral separation is based more on the symptoms of the individual athlete. Once the athlete experiences decreased symptoms such as minimal pain and normal respirations, return to play may be considered. The timeline for a returning athlete also depends on the sport. Athletes participating in contact sports may have a more delayed return based on the type of rib injury and the risk of further reinjury. Contact sport athletes may require a rib belt or padding if early return to play is considered.

Prevention

Rib injuries can rarely be prevented as they are typically caused by trauma. Contact sport athletes may consider appropriate rib padding to prevent the impact of repeated blows to the rib area.

Douglas Comeau

See also Costosternal Syndrome (Costochondritis); Rib Fracture and Contusions; Rib Stress Fracture; Trunk Injuries

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Bulimia Nervosa

It has often been noted that contemporary American popular culture is marked by an obsession with thinness and weight loss. At the same time, there is a worldwide epidemic of overweight and obesity. Many people strive to lose weight for health or aesthetic reasons. Most use healthy methods such as decreasing their caloric intake and/or increasing their physical activity. Some use unhealthy methods such as abusing stimulants, laxatives, or diuretics or intentionally acquiring gastrointestinal infections. For some people, weight loss becomes an obsession, marked by persistent and pervasive worries about body image, weight, or athletic performance. Some of these people develop maladaptive eating, exercise, or other behavioral patterns that can lead to serious health problems or even death. These patients are said to have an *eating disorder*. The American Psychiatric Association's *Diagnostic and Statistical Manual of Mental Disorders,* fourth edition (*DSM-IV*) identifies three distinct types of eating disorders: anorexia nervosa, bulimia nervosa, and eating disorders not otherwise specified (ED-NOS). Anorexia and eating disorders are discussed elsewhere.

Epidemiology

Compared with anorexia nervosa, bulimia nervosa has been recognized as a diagnosis for a shorter period of time, and the diagnostic criteria have changed from previous editions of the *DSM*. For this reason, incidence and prevalence data are difficult to interpret. Bulimia is clearly more common in women and in college students. Prevalence rates are likely between 1% and 1.5% of women. This compares with a lifetime prevalence of 0.9% for anorexia nervosa in women.

Diagnosis

The lay public commonly defines *bulimia* as forced vomiting after meals. This is an incomplete and misleading definition. While vomiting may be associated with bulimia, the hallmark of the disorder is really a sense of lack of control over eating and the use of excessive compensatory behaviors to prevent weight gain. The *DSM-IV* definition of bulimia nervosa is outlined below (American Psychiatric Association, 1994, p. 549):

- There are recurrent episodes of binge eating. An episode of binge eating is characterized by both of the following:
  - o eating, in a discrete period of time (e.g., within any 2-hour period), an amount of food that is definitely larger than most people would eat during a similar period of time and under similar circumstances, and
  - o a sense of lack of control over eating during the episode (e.g., a feeling that one cannot stop eating or control what or how much one is eating).
- There is recurrent inappropriate compensatory behavior to prevent weight gain, such as self-induced vomiting; misuse of laxatives, diuretics, or other medications; fasting; or excessive exercising.

- The binge eating and inappropriate compensatory behaviors both occur, on average, at least twice a week for 3 months.
- Self-evaluation is unduly influenced by body shape and weight.
- The disturbance does not occur exclusively during episodes of anorexia nervosa.
- Specific types are as follows:
  - *Purging type:* The person regularly engages in self-induced vomiting or the misuse of laxatives or diuretics.
  - *Nonpurging type:* The person uses other inappropriate compensatory behaviors, such as fasting or excessive exercise, but does not regularly engage in self-induced vomiting or the misuse of laxatives or diuretics.

Patients with bulimia nervosa rarely complain to their health care provider without the encouragement of friends or family members. In addition, they are often of normal weight, appear healthy, and have normal menstrual periods, which may mislead the examiner into thinking that they have healthy eating habits. The astute clinician may notice physical examination findings suggestive of purging behavior, such as erosions of the dental enamel, hypertrophy of the parotid glands, calluses on the dorsum of the fingers (the Russell sign), or damaged fingernails. Electrolyte abnormalities can be seen with laxative or diuretic abuse. Frequent stress fractures or other musculoskeletal injuries may occur in those who engage in excessive exercise.

Because identifying patients with bulimia nervosa (or other eating disorders) can be challenging, several screening tools have been developed. Among the most common are the SCOFF and *E*ating Disorder *S*creen for *P*rimary Care (ESP) questionnaires and the Eating Attitudes Test (EAT). Each has good sensitivity and specificity for eating disorders in general. However, additional interviewing and a good rapport with the patient are required for the clinician to make a definitive diagnosis of bulimia.

Vital sign abnormalities, such as low heart rate, orthostasis, and low body temperature, may be seen in patients who are severely malnourished due to an eating disorder. Rarely, fatal bradyarrhythmias may occur in the setting of profound malnutrition (especially protein and phosphorus depletion) and electrolyte abnormalities.

Laboratory evaluation for electrolyte abnormalities is necessary in patients who have been abusing laxatives or diuretics, have significant malnutrition, or vomit frequently. In addition, it may be useful to assess for other conditions that can mimic eating disorders, such as new-onset diabetes mellitus, adrenal insufficiency, gastrointestinal disease, or thyroid disease.

Other psychiatric illnesses, especially major depression, can be confused with eating disorders. This is more common with anorexia but can occur with bulimia nervosa as well. It is important to have the patient evaluated by a psychiatrist or psychologist with substantial experience with eating disorders to help assess for comorbid psychiatric illness early in the treatment course in order to maximize the patient's likelihood of recovery.

Treatment

A multidisciplinary team consisting of a medical provider, a dietitian, and a mental health provider should work together to treat patients with bulimia nervosa. While the disease can be difficult to manage, cognitive behavioral therapy, other psychotherapies, antidepressant medications, and a combination of antidepressant medication with psychotherapy have all been shown to provide some benefit. Patients with severe malnutrition may be at risk for refeeding syndrome and should be managed in a medical ward or in the ICU (intensive care unit), with frequent monitoring of their cardiac function and electrolytes. While a complete discussion of the treatment of bulimia is outside the scope of this entry, the American Psychiatric Association and the Society for Adolescent Health and Medicine have published detailed treatment guidelines for adolescents and adults with eating disorders.

Andrew R. Peterson

See also Anorexia Nervosa; Dietician/Sports Nutritionist; Obesity; Psychological Assessment in Sports

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Bunions

A bunion, also called *hallux valgus*, is an enlargement on the inside of the big toe joint, resulting in the big toe leaning toward the second toe. This deformity is a common and usually an inherited trait. The resultant malalignment of the big toe joint and the bony prominence result in a painful deformity that makes wearing shoes difficult, necessitating treatment. While bunions are not associated with narrow shoes or high heels, there is a higher incidence in females. Most bunions can be treated successfully with conservative or surgical intervention.

Diagnosis

History

Bunions are a common foot deformity that has been estimated to affect approximately 1% of the population. The incidence of the deformity has been found to increase with age due to the progressive nature of the deformity. The deformity begins with a leaning of the big toe, gradually changing the angle of the bones over the years and slowly producing the characteristic bump on the side of the big toe (Figure 1).

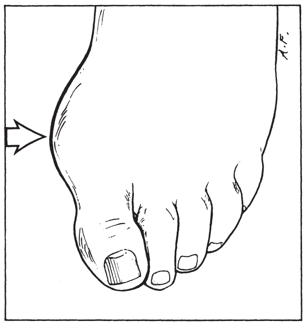

Figure 1 A Typical Bunion

Bunions have been thought to be caused by a variety of underlying conditions, such as faulty biomechanics of the foot, neuromuscular disorders, and arthritic conditions. The prevailing theory is that the deformity is caused by an inherited faulty mechanical structure of the foot. Thus, it is not the bunion itself that is inherited but certain foot types that make a person prone to developing a bunion.

The pain symptoms associated with bunions typically appear at later stages, well after the deformity becomes evident. These pain symptoms are typically aggravated by activity such as walking or running, as well as by shoes that create pressure along the bony prominence. However, some people with bunion deformities may never experience pain symptoms.

Although wearing narrow shoes that crowd the toes is not the cause of the bunion deformity, it can aggravate the pain symptom, causing symptoms sooner. Most individuals complain of pain in the area of the bony prominence. These pain symptoms are usually aggravated by pressure in the area. Occasionally, compression of a nerve by the bunion area will cause symptoms of tingling and numbness.

Bunion deformities in the athlete and the dancer may be particularly painful due to the snug fit of athletic shoes such as cleats and pointed shoes. Additionally, the strenuous activities may aggravate the area, creating a chronic inflammatory condition. Bunions are particularly prevalent in ballet dancers, and it is felt that while ballet itself is not the cause of the deformity, the forces through the foot during dancing produce an environment in which bunions may develop.

Physical Examination

Bunions can be recognized on visual examination of the foot. There is a characteristic prominence to the inside of the big toe joint with leaning of the big toe toward the second toe. In early deformities, the big toe joint is flexible and the deformity can be manually reduced. In later stages, the joint may stiffen, and range of motion diminishes.

In many individuals with bunions, there may be an associated hypermobility noted in the foot that may be a contributing factor to the development of the bunion. These individuals may exhibit a flat foot deformity. However, not all bunions are associated with flat feet.

Initial examination of the bunion may involve determining the area of pain, which is usually located at the bony prominence of the big toe joint. Signs of inflammation, such as swelling, redness, and increased warmth, may also be noted in this area. Examination of the motion of the joints in the foot may also be performed to determine the stage of the deformity.

Imaging Studies: Radiography

Radiographic evaluation of the bunion includes examination of the alignment of the bones involved in the deformity. The angle formed by the first metatarsal and the second metatarsal is measured to determine the severity of the bunion deformity. The angle formed by the first metatarsal with the proximal phalanx in the big toe is also measured to determine the extent of the big toe angulation toward the second toe.

The first metatarsophalangeal joint is evaluated for congruency. As the bunion deformity progresses, the joint will become less congruous. The position of the sesamoid bones will also start to shift laterally as the bunion deformity progresses. The subluxation of the sesamoid bones generally results in joint incongruity. Evaluation of these radiographic parameters will enable the doctor to determine how severe the deformity is and will give some guidance in selecting treatment options.

Treatment

Initial Treatment

Initial treatment is typically aimed at easing the pain of the bunion. This can be achieved through methods to alleviate the inflammation associated with the bony prominence or the impinged nerve. However, it is important to note that conservative treatment will not correct the bony deformity or halt its progression. Thus, after the pain symptoms resolve, the bony deformity persists and can result in recurrence of the pain symptoms.

Treatment options include the following:

- *Changes in footwear:* The patient may be recommended shoes that have a wide toe box and asked to forgo those with pointed toes or high heels, which may aggravate the condition.
- *Padding:* Pads placed over the area of the bunion can help minimize pain. These bunion pads are typically found in drugstores.
- *Activity modifications:* Activity that causes bunion pain should be avoided, such as certain sports activities.
- *Medications:* Nonsteroidal anti-inflammatory drugs (NSAIDs), such as ibuprofen, may help relieve pain.
- *Icing:* Applying an ice pack several times a day helps reduce inflammation and pain.
- *Injection therapy:* Although rarely used in bunion treatment, injections of corticosteroids may be useful in treating the inflamed bursa (fluid-filled sac located in a joint) sometimes seen with bunions.
- *Orthotic devices:* In some cases, custom orthotic devices may be provided to decrease the pain symptoms as well as to decrease the motion that may be aggravating the bunion.
- *Physical therapy:* Physical therapy may help relieve the pain symptoms associated with inflammation of the joint.

Surgical Treatment

In athletes and dancers, surgical intervention is typically considered the last resort, given the amount of time needed for recovery as well as the residual stiffness experienced after surgery. However, in some instances, the bunion deformity will be painful or large enough so that conservative care may not be sufficient to relieve the symptoms. Additionally, subluxation of the sesamoids resulting in incongruity of the joint may make surgical relocation necessary. In these cases, surgery may be required to treat the bunion deformity.

The type of surgical treatment will depend on the severity of the deformity. Most procedures used for treating hallux valgus involve performing an osteotomy and soft tissue balancing procedures to realign the joints in the proper position. Following surgery, it may take several months before the athlete can return to his or her sport.

Prevention

It is unclear as to whether the bunion deformity can be prevented. However, the pain symptoms associated with the bunion can be prevented by wearing appropriate shoes to remove the pressure from the deformity. Additionally, avoidance of activities that aggravate the symptoms will help decrease pain.

Return to Sports

An athlete may return to sports once the pain symptoms stop. If conservative care is given, the pain symptoms may recur due to the continued bunion deformity. However, the use of appropriate shoes to accommodate the deformity and inserts to reduce the biomechanical stress may reduce the recurrence rate.

Thanh Dinh

See also Arthritis; Biomechanics in Sports Medicine; Corns; Nonsteroidal Anti-Inflammatory Drugs (NSAIDs); Orthotics

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Burnout in Sports

Athlete burnout is a negative experiential syndrome. The most widely employed description of the syndrome has come from the work of Dr. Tom Raedeke. He has demonstrated that the athlete burnout syndrome is characterized by an enduring experience of three key symptoms: (1) emotional and physical exhaustion, (2) sport devaluation, and (3) reduced accomplishment. This sport-specific conceptualization is grounded in Christina Maslach's research in other work settings and has been modified to have particular relevance to sports. Unfortunately, in addition to this syndrome, the term *burnout* is often loosely employed to cover a variety of other potentially interrelated experiences, including sport dropout and overtraining-related underperformance (i.e., "overtraining syndrome"). Although interrelated to some degree, the burnout and overtraining syndromes, in particular, differ in diagnosis and treatment, and it is important that they are not confused.

Researchers have found that a relatively small proportion of athletes involved in serious competition experience burnout to an extent that results in negative performance and personal welfare outcomes. Consequently, the early identification and treatment of burnout is important from both athlete welfare and performance perspectives. Readers should be mindful that athlete burnout is currently a developing area of research. Current knowledge on potential antecedents, early signs, symptoms, consequences, and treatment is outlined in this entry; further research advances are likely to emerge.

Potential Antecedents

Burnout is proposed to be the result of excessive psychological and physical demands. As such, athletes at the highest risk of experiencing the burnout syndrome tend to be involved in serious organized sports with demanding competitive schedules and regimens of formalized training. In contrast, athlete burnout is unlikely to be an issue of particular relevance among recreational sports participants.

The ongoing demands of sports differ in important ways from those found in other settings in which burnout has been studied. Moreover, there is also variation in the demands associated with athlete burnout across different sports. As a consequence, identification of a comprehensive list of potential antecedents is not possible. To date, some common antecedents identified across sports settings include intense competitive involvement, high competition load, heavy training, injury, demanding travel schedules, media and public demands, pressure to perform, risk of nonselection or deselection from a team, poor performance, and playing in underrecognized but physically demanding positions that are important to team performance.

Demands outside an individual's direct sports involvement have also been associated with athlete burnout. For example, financial stressors and concerns about not being able to fulfill educational and nonsport career aspirations may color the way athletes view their sports involvements. These perceptions may lead athletes to believe that they are effectively trapped by (or within) their sports involvements, which can, in turn, initiate or exacerbate feelings of exhaustion, alienation, and cynicism about those sporting involvements.

Possible Early Signs

Identification of early signs indicating risk for athlete burnout enables a proactive approach to the management of the syndrome. It may be considered normal for athletes involved in intense competition to intermittently present with some early signs. Nonetheless, once presentation of a sign (or signs) becomes more frequent, the athlete would be considered at risk of experiencing burnout.

Early signs of risk for athlete burnout can be found in the increase in ongoing difficulties in meeting sporting and personal obligations. Athletes at risk of suffering from burnout may also exhibit strained social interaction and communication patterns or report being unhappy with their social lives. Early signs might also manifest in the form of restricted participation in previously valued alternate activities, particularly when the athlete attributes this change to exhaustion. Finally, an athlete at risk of burnout may report feeling that he or she is not receiving adequate support from significant others, including the coaching and support staff, other players, spouses, and friends. As these are the athlete's perceptions, the beliefs may or may not accurately represent the situation.

Symptoms

In essence, a syndrome is a group of symptoms that present as defining features for a condition. In the case of athlete burnout, the symptoms are most logically grouped by the key characteristics—emotional and physical exhaustion, sport devaluation, or reduced accomplishment. Large variations in athletes' stress perceptions and experiences have been well documented; as a result, *representative* symptoms are identified here. The chronological order in which the burnout characteristics emerge is yet to be established. Preliminary evidence suggests that physical and emotional exhaustion may result in performance declines, subsequent feelings of reduced accomplishment, and, finally, devaluation of the sport. Alternatively, based on current research, it is equally plausible that poor performance may result in feelings of reduced accomplishment, while subsequent redoubling of efforts to rectify performance may then lead to sport devaluation.

Emotional and Physical Exhaustion

Athletes suffering from burnout experience a prolonged sense of being both emotionally and physically exhausted. This feeling of exhaustion is *not transient,* as is often experienced during episodes of demanding competition or training, which subsequently recedes after relatively short periods of rest. Instead, burnout-related exhaustion is *chronic.* These prolonged feelings of exhaustion have been associated with factors such as ongoing and unrelenting exposure to emotionally and physically draining competitive circumstances (sometimes intensified by media scrutiny), demanding and/or extended travel schedules, and intense training regimens. Athletes experiencing burnout typically report that they do not feel emotionally and/or physically refreshed after routine breaks in competition and training. Moreover, they often feel unable to "turn the experience around."

Reduced Accomplishment

A lingering (or enduring) sense of reduced accomplishment, especially among athletes who have no objective reason to feel this way, can be a key symptom of burnout. Athletes experiencing burnout may perceive that their contributions to the team are relatively unimportant, even in instances when, objectively, their contributions are substantial. Independent of their own perceptions of contribution, athletes may also feel that significant others within the team environment do not value their contributions. For athletes suffering from burnout, these feelings are not transitory and often include misgivings about their ability to perform as they would like in the future. It is not at all unusual for these athletes to feel that their careers are not progressing as they would like. These feelings of reduced accomplishment are often closely related to feelings of sport devaluation.

Sport Devaluation

Players experiencing burnout will typically devalue their sports participation to the point where they question the value of their participation. This devaluation allows athletes to psychologically distance themselves from the formerly valued activity in a way that protects their self-esteem. It is much easier to back away from commitments that are of lesser importance than those that have very high personal value. As such, some symptoms include doubts about the cost-benefit ratio associated with their athletic involvement (e.g., "Is this really worth it?" "Why am I doing this?") and loss of enjoyment of the sport and the desire to train and compete. These reservations can result in an unwillingness to examine poor performances for future improvement and a decreased enthusiasm for the challenging training required to extend skills and physical capabilities.

Consequences

Preliminary research has associated athlete burnout with negative consequences such as decreased motivation/commitment (including psychological and sometimes physical withdrawal), decreased performance levels, impaired health, personal dysfunction, insomnia, misuse of alcohol and drugs, as well as marital and family problems.

The consequences of athlete burnout are likely to exacerbate the negative way in which these athletes view their sports participation. For example, athletes experiencing a loss of enthusiasm may be reluctant to complete the repetitions necessary to perfect moves or lack the motivation to self-initiate individual training sessions, resulting in decreased performance levels and nonselection. In turn, nonselection has consequences for financial remuneration and athlete confidence and is, in and of itself, a recognized antecedent.

Diagnosis

Although measures of athlete burnout have been developed and validated for research purposes, no tools currently exist to assist in the clinical diagnosis of athlete burnout. Current definitions suggest that an enduring experience of all three burnout characteristics is required. This is not to say that the chronic experience of just one characteristic will not result in potential negative welfare and performance consequences; it is only to suggest that a diagnosis of burnout may not be warranted if all three syndrome characteristics are not evident. Athletes displaying symptoms relating to all three characteristics over a prolonged period, however, should be regarded as potentially progressing into or experiencing burnout. Of course, any burnout diagnosis would involve assessments ruling out other potentially related conditions of concern (e.g., depression, overtraining syndrome).

Perhaps one of the most challenging aspects of identifying that an athlete is experiencing burnout is the differentiation between burnout and overtraining syndrome. While researchers are still working on clear delineations of these phenomena, two key issues are clear. Clearly, the stress of training demands can exacerbate athletes' progression into burnout, but it is also the case that athletes can progress into burnout without any involvement of overtraining. In contrast, overtraining syndrome, by definition, requires athlete overtraining. Moreover, preliminary evidence suggests that burnout is associated with shifts toward motivated sports participation, while overtraining syndrome is brought on and maintained by high levels of training motivation and commitment.

Treatment

To date, researchers have presented a number of potential strategies for assisting athletes with burnout. Intervention evidence is available from burnout research in other workplace settings, but refinement of athlete-specific strategies into well-tested intervention programs has yet to occur. As a result, the current discussion is limited to a description of approaches and proposed strategies that may be suitable for athletes.

Strategies can be implemented to both manage and/or prevent burnout. These strategies to prevent and/or manage burnout can be implemented at personal (e.g., skills) or organizational (e.g., management strategies) levels. Overall, workplace burnout intervention research has had a bias toward examining personal strategies rather than organizational strategies because personal-level interventions are easily implemented and have lower organizational costs. These strategies have tended to concentrate on the management of symptoms and early signs, rather than on prevention. The primary assumption of these personal management interventions is that individuals are aware (or can be made aware) that they are experiencing (or are at risk of experiencing) burnout and, furthermore, that they are interested in implementing strategies to address that concern. Despite the negative consequences of stress potentially making it harder for participants to use strategies, personal-level management strategies have had demonstrated success in preventing and reducing burnout outside sports.

Some specific personal management strategies evaluated as effective in past research include common stress management techniques such as cognitive restructuring, development of time management skills, and relaxation exercises. These types of personal management strategies can be employed to equip athletes for dealing with potential burnout antecedents such as injury, poor performance, and perceived risk of nonselection. Organizational-level strategies with a potential to manage burnout might include efforts to enhance athletes' perceptions of autonomy, choice, and control over their careers; career opportunities, training, and development of competencies beyond sports; and support of the athletes' relational and familial responsibilities. Organizational-level strategies could also address potential antecedents relating to season and rest break structure (time off training and competition). While these organizational-level strategies are yet to be evaluated in sports, studies in nonsport settings have produced some positive results.

Scott L. Cresswell and Robert C. Eklund

See also Benefits of Exercise and Sports; Overtraining; Psychological Aspects of Injury and Rehabilitation; Psychology of the Young Athlete

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Bursitis

Bursitis is inflammation of a bursa. *Bursae* (plural for bursa) are lubricating sacs that overlie bony prominences to prevent friction between skin and bone and between tendons or ligaments and bones. There are approximately 160 bursae located throughout the body. The largest joints—shoulder, hip, knee, and elbow—are the sites of the major bursae and are the areas most commonly affected with bursitis. Symptoms of bursitis include stiffness after inactivity and pain with movement of the adjacent joint.

Anatomy

Bursae are small sacs lined with synovium, a thin membrane that secretes a clear, viscous (thick) lubricating substance called synovial fluid. They are located in areas of friction where skin, tendons, and ligaments move across bony prominences. If bursitis becomes chronic, the synovial fluid within the bursa can become thickened and calcified from prolonged swelling. The most commonly affected bursae are the subacromial, olecranon, trochanteric, prepatellar, infrapatellar, pes anserine, and retrocalcaneal.

The subacromial bursa is located in the shoulder, just inferior (below) to the acromion of the scapula (shoulder blade) and above the rotator cuff. The olecranon bursa is located just under the skin at the posterior (back) elbow at the olecranon of the ulnar bone. The trochanteric bursa lies over the greater trochanter of the lateral (outer) hip. The prepatellar bursa is located between the skin and the patella (knee cap) and the infrapatellar bursa is just inferior (toward the foot) to the patella, surrounding the patellar tendon. The pes anserine bursa is located on the medial (inner) leg, just inferior to the knee. It lies between the tibia bone and the attachment of three muscle tendons: semitendinosus of the hamstrings, gracilis, and sartorius.

Symptoms

Initially, symptoms of bursitis will be noticed only during activity or when pressure is applied directly over the bursa. For example, it is common for people with trochanteric bursitis to complain of hip pain when they lie on the affected side. Pain is also noted to worsen after a period of inactivity, such as stepping out of a car after a long trip. Edema (swelling), erythema (redness), and radiating pain to adjacent structures may also occur. As the inflammation progresses, symptoms become more severe, occurring at rest or with minimal movement. This is seen in subacromial bursitis, in which patients commonly report pain that awakens them at night. Prolonged inflammation can lead to thickening of the synovium, calcification of the synovial fluid, and chronic swelling. In these cases, the bursa is no longer acting as a lubricating pad. Partial tears or complete rupture of adjacent muscles or tendons may then occur from excess friction. In this case, weakness would be reported in addition to pain.

Causes

Bursitis can be caused any mechanism that can irritate a bursa. The most common cause is trauma, either repetitive or acute. Examples of areas of repetitive trauma are the acromial bursa of the shoulder in throwing athletes and the knee or hip in runners. Bursitis from acute trauma is more commonly seen over bony prominences such as the greater trochanter or olecranon after a fall. Other causes include infection, gout, and rheumatoid arthritis, as well as other medical conditions that involve the immune system.

Treatment

Treatment of bursitis is most successful during the earliest stages of the inflammatory process. Conservative management includes ice, nonsteroidal anti-inflammatory medications such as ibuprofen, and avoidance of activities that cause pain or irritation to the affected bursa. If symptoms become chronic or severe or if there is excessive edema, an inflamed bursa can be aspirated (fluid removed with a needle) and then injected with a corticosteroid, with or without a local anesthetic. In cases where there is no history of trauma, diagnostic aspiration may be indicated to evaluate the fluid for infection or systemic disease processes. In rare cases where conservative treatment fails and patients have severe, recurrent symptoms, surgical excision (removal) of the bursa may be necessary.

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See also Achilles Bursitis; Elbow Bursitis; Knee Bursitis; Pelvic Bursitis; Shoulder Bursitis; Trochanteric Bursitis

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C

Caffeine and Exercise

Caffeine (1,3,7-trimethyl-1H-purine-2,6(3H,7H)-dione) is the world's most widely used ergogenic (external influences that positively affect mental or physical performance) pharmacological aid. Caffeine has been used for over 5,000 years, dating back to when the Chinese first discovered tea. Today, the substance is primarily consumed in the form of coffee and other beverages. Caffeine is found in coffee beans, the tea bush, the kola nut, guarana berries, yerba mate, and cocoa. Caffeine is commonly used in pill form (NoDoz®), is sometimes used in combination with over-the-counter pain relief medication (Excedrin®), and has recently been incorporated into the growing market of energy drinks (Red Bull®, Monster®). Historically, the stimulant has been used to increase alertness and reduce physical fatigue; however, more research is being done to elucidate the effects of caffeine on athletic performance.

The effective ergogenic dose of caffeine has been reported to be 3 to 9 milligrams/kilogram (mg/kg) of body weight. Caffeine is primarily absorbed in the stomach and small intestine and has peak blood concentrations at about 45 minutes after intake. The chemical is distributed throughout all tissues of the body and is capable of crossing the blood-brain barrier. In healthy adults, caffeine has a half-life of about 3 to 4 hours. However, oral contraceptives, pregnancy, and liver failure can extend the half-life substantially. Caffeine is metabolized in the liver by a cytochrome P450 oxidase enzyme system (1A2). The three metabolic by-products, paraxanthine (80%), theobromine (10%), and theophylline (4%), have various effects on the body. These metabolites are broken down and excreted in the urine.

General Cardiovascular Effects

Caffeine and its metabolites have effects on the cardiovascular system that are thought to enhance athletic performance. Theobromine is a vasodilator that helps increase oxygen and nutrient delivery to muscle and brain tissues. Theophylline increases heart rate and heart contractility and, therefore, increases cardiac output (the amount of volume pumped by the heart per unit time). Large overdoses of caffeine can create cardiac complications, including heart palpitations and heart attack.

General Respiratory Effects

In addition to the vascular effects, caffeine also contributes to an increase in respiratory function. Theophylline acts as a smooth muscle relaxant of the bronchioles and, thus, increases lung ventilation and oxygen saturation. Caffeine is being researched as a potential drug for use in athletes with exercise-induced asthma. Caffeine is also thought to stimulate the respiratory center of the medulla and, thus, increase the ventilation rate. Caffeine can therefore increase respiratory readiness and prepare the body for athletic activity by increasing overall blood oxygen concentrations.

Dehydration and Renal Effects

One of the common worries about the consumption of caffeine is dehydration. While caffeine has shown mild diuretic (water excretion) effects on the kidney, consuming caffeinated beverages does not show a significant increase in overall fluid loss in a 24-hour period. Therefore, athletes should not increase their fluid intake when using moderate amounts of caffeine (<456 mg). However, when large ergogenic doses are taken, the risk of fluid loss is higher, and more water should be consumed to prevent hypovolemia (a drop in blood pressure). Regardless of caffeine intake, athletes should always monitor fluid intake during heavy training regimens.

Effects on Endurance and Aerobic Exercise

Because of the proven cardiovascular and respiratory effects of caffeine, the effects on endurance athletes (swimming, running, cycling) are being researched in depth. Athletes in endurance sports report an increase in performance in long-distance events, with very little side effects. These athletes typically consume caffeine in a beverage or gel form and report doses of 3.8 mg/kg of body weight. Caffeine has also been shown to increase the time needed to reach the maximum rate of ventilation in endurance athletes during aerobic threshold training. Athletes therefore do not reach their maximum ventilation rate until later in the exercise. The vasodilation of peripheral blood vessels helps decrease total vascular resistance, thus increasing muscle and brain perfusion. This allows oxygen and nutrients to be delivered to the muscles, heart, and brain more efficiently, thus promoting faster recovery. Finally, while caffeine has been shown to shift metabolism toward breaking down fats, the long-term effects of caffeine use in endurance athletes has not been shown to include a change in body composition. In general, caffeine can be used to increase mental performance and concentration during all types of athletic events.

Effects on High-Resistance, Explosive, and Anaerobic Exercise

Acute dosing of caffeine prior to explosive training (weight lifting, sprinting) has shown beneficial effects as well. Caffeine is thought to increase muscle contractility by enhancing the release of calcium and increasing neuromuscular transmission. Agility and focus during sports have been shown to increase when taking effective doses of caffeine. In addition, caffeine has been shown to replenish muscle glycogen stores faster when co-ingested with carbohydrates. This allows the athlete to perform explosive exercise for a longer duration of time. In addition, because of the effects of theophylline, cardiovascular output can be increased rapidly while working with increased muscle after load or contraction. However, overall maximal speed and power have not been shown to benefit from caffeine dosing.

Effects on Recovery After Exercise

Several studies have shown that caffeine in combination with complex carbohydrates (energy drinks, sugar, juices) allows for muscle glycogen to be replenished faster. The increased glycogen stores allow for increased performance in the next workout cycle. Caffeine also changes the body's metabolism to use more fats. Fats have more energy per gram and can therefore fuel athletes for greater endurance.

Effects on Concentration and Memory

Caffeine has many effects on the central nervous system (CNS). Caffeine and its metabolites have been shown to change chemical signaling in the brain. The changes allow for faster recognition of stimuli and increased processing of information. This can have a beneficial effect on concentration during sports competitions. For example, caffeine has been shown to increase the focus level in sports such as tennis and soccer. In other studies, consistent low doses of caffeine have been associated with decreased function in the long-term memory centers of the brain. These processes are yet to be fully elucidated.

Tolerance, Addiction, and Overuse

Because caffeine has an effect on some neurotransmitters in the CNS, over time and with consistent dosing (a cup of coffee a day), caffeine can induce tolerance adaptation. In this type of tolerance, the body adapts itself to the current dose, and thus higher doses are required to elicit an ergogenic effect. At the same time, a sudden decrease in caffeine usage will create withdrawal symptoms, because of the way the body has adjusted to a baseline caffeine intake. Caffeine tolerance has been induced when taking more than 300 mg/day for about 7 days. Therefore, to optimize the effect of caffeine for a sporting event, abstinence from caffeine for several days is thought to increase the acute dosing effects.

Withdrawal symptoms include headache, irritability, inability to focus, and stomachaches. These symptoms typically occur 12 to 24 hours after a previous dosage. Resolution of withdrawal can typically take 1 to 5 days.

Caffeine abuse and overuse is known as caffeinism. One can become caffeine dependent and take large doses daily. Symptoms include nervousness, irritability, anxiety, tremulousness, muscle twitching (hyperreflexia), insomnia, headaches, respiratory alkalosis, and heart palpitations. Neurological disorders include caffeine-induced anxiety disorder and caffeine-induced sleep disorder.

Athletic Regulations

Historically, caffeine and ephedrine have been consumed in combination by elite athletes; this combination has been banned by all sporting and athletic organizations. Caffeine use, however, is still permitted in major sporting events. The International Olympic Committee (IOC) has set limitations on the use of caffeine to less than 12 micrograms/milliliter (μg/ml) in the urine. The National Collegiate Association of Athletics (NCAA) has set the limitation slightly higher at 15 μg/ml in urine testing. These doses are about the equivalent of 800 mg of caffeine, which is above the dose needed to create an ergogenic effect. For reference, a single cup of coffee contains about 120 mg of caffeine.

Coffee Versus Caffeine

Some of the acute ergogenic effects of caffeine have not been reproduced when drinking the equivalent doses of coffee. Further studies are being done to tease out the benefits of coffee intake versus caffeine intake.

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See also Dehydration; Doping and Performance Enhancement: A New Definition; Doping and Performance Enhancement: Historical Overview; Doping and Performance Enhancement: Olympic Games From 2004 to 2008; Nutrition and Hydration

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Calcium in the Athlete's Diet

Calcium is the most prevalent mineral found in the human body. Calcium is chemically classified as an alkaline earth metal, which is a substance that forms ions. Ions have an electrical charge, thus they bind with the free electrons in these metals. The metallic bond formed by such metals tends to make these elements good conductors of both heat and electricity.

Calcium is not often found in its pure state in nature, as its ability to bond causes it to readily form compound substances such as calcium carbonate, or calcite, the essential component of limestone. Minerals are substances that are mined from the earth; although it is not extracted in its pure form, calcium is defined as a mineral for the purposes of understanding its role in the function of the body.

The Function of Calcium

Calcium is an essential mineral that is important for bone health. It is also important for normal enzyme activity and muscle function. Approximately 90% of the total body calcium is stored in the bones and teeth. This results in approximately 2.2 pounds (lb; 1 kilogram [kg]) to 3 lb (1.4 kg) of calcium contained in the body of an average healthy adult. Calcium is constantly being turned over in bone, with resorption and deposition happening simultaneously to maintain it in an active steady state. It is required for bodily functions such as muscle contraction, blood clotting, central nervous system activity, and regulation of heart rate. Calcium is lost through sweat, urine, and feces. Daily intake of calcium is necessary to replenish the body and maintain the calcium stores. Absorption of calcium in the gastrointestinal tract depends on the availability of active 1,25-dihydroxyvitamin D (1,25-Vit D-OH). Vitamin D is regulated by the parathyroid hormone (PTH) and parathyroid gland. Low calcium levels trigger PTH release and vitamin D conversion in the kidney, which, in turn, increases absorption of calcium from the gut and also from bone.

Healthy bone development, maintenance, and repair are directly related to optimum levels of calcium. Bones are constructed of calcium phosphate and collagen protein. The bone components form a mesh of the very hard calcium phosphate and the softer collagen. Bone metabolism is a very active process in the body, with cells known as osteoblasts (bone-formation cells) and osteocytes (bone-lining cells) continually processing calcium for bone construction. Bone metabolism is not a protected process in the body as calcium is removed from the processes of bone formation when it is needed for other essential functions such as muscle contractions. Bone formation and bone mineralization are compromised when the calcium level is low due to poor dietary intake. Similarly, too little vitamin D will inhibit calcium utilization, which leads to a similar consequence. Excess intake of calcium leads to the risk of the formation of calcium oxalate, a compound that forms in the kidneys and is the chief component of kidney stones.

Table 1 Recommended Daily Intake of Calcium

Age (years)	*Daily Requirements (mg/day)*
6–10	800–1,300
11–18	1,200–1,500
19–50	1,000
Over 50	1,200

Recommended Daily Calcium and Vitamin D Intake

There are variations in the recommendations of daily calcium intake. Children from 6 to 10 years of age require 800 to 1,300 milligrams (mg)/day, and children from 11 to 18 years of age require 1,200 to 1,500 mg/day. Adults from 19 to 50 years of age require 1,000 mg/day, and people over the age of 50 need 1,200 mg/day. The tolerable upper limit for calcium intake is 2,500 mg/day for all age-groups. Calcium supplementation has been recommended, especially in women, to augment dietary calcium intake. Calcium carbonate and calcium citrate are the most common forms of supplements available commercially. Calcium carbonate generally contains about 40% elemental calcium, while calcium citrate generally contains approximately 21%. In general, calcium carbonate costs less and is best absorbed with meals. Calcium citrate can be taken anytime and is preferred in patients with chronic constipation. Patients who take H2 blockers for gastroesophageal reflux or other stomach acid disorders often tolerate calcium citrate better. Doses are generally 500 to 1,000 mg daily and should be divided into two or more doses spread throughout the day to improve absorption (Table 1).

What Should Athletes Know About Calcium Supplements?

The amount of calcium in supplements varies from 200 to 600 mg and should be printed on the label. Serving sizes vary and are often two tablets at a time. Most often, chewable tablets are absorbed better than pills that are swallowed whole.

Vitamin D is required for adequate calcium absorption, regulation of serum calcium and phosphorus, and promotion of bone health. It is estimated that only 50% of girls aged 9 to 13 years and 32% of girls aged 14 to 18 years get the recommended daily intake of 400 international units (IU) of vitamin D. Vitamin D intake should range from 400 to 1,000 IU/day from food plus supplements. Adequate dietary calcium intake in the absence of adequate vitamin D adversely affects bone health.

Calcium is present in a wide variety of foods and beverages, with cow's milk, soy milk, yogurt, and cheese serving as the major dietary sources for Americans. Certain vegetables such as broccoli and spinach, tofu, salmon, sardines, fortified juices, and grains also serve as good dietary sources of calcium (Table 2). Improvement in vitamin D levels is achieved by eating vitamin D–rich and–fortified foods, taking calcium and vitamin D supplements, taking yearly vitamin D injections, and getting regular exposure to sunlight.

Adverse Effects of Inadequate Calcium Intake on Bone Density

Low calcium intake is an epidemic in our adolescent youth population. It is estimated that only 13.5% of girls and 36.3% of boys get the recommended daily intake of calcium. Inadequate dietary calcium intake in this age-group, particularly in females, is of great concern with regard to bone

Table 2 Examples of Nutritional Sources of Calcium

Food Source	*Serving Size (g or ml)*	*Calcium Content (mg)*
Milk (whole, low fat, skim, chocolate)	240 ml (1 cup)	275–300
Calcium-fortified fruit punch or orange juice	240 ml (1 cup)	300
Broccoli	85 g (1½ cup)	40
Cheddar cheese	45 g (1.5 oz)	300
Cottage cheese	240 g (1 cup)	160
Part-skim mozzarella	45 g (1.5 oz)	300
Chinese cabbage leaves or mustard greens	85 g (1½ cup)	240
Kale	85 g	60
Nuts (almonds)	35 g (½ cup)	160
Pudding (chocolate)	35 g (½ cup)	160
Salmon	100 g	140
Soybeans	35 g (½ cup)	200
Spinach	85 g	115
Tofu with calcium	120 g	260
Vanilla ice cream	35 g (½ cup)	85
Yogurt (nonfat and low fat)	240 g (8 oz)	400–450
Yogurt (frozen)	240 g (8 oz)	100

Note: 1 ounce (oz) = 29.57 ml.

mineral density (BMD). Ninety percent of peak bone mass is attained by age 18. Testosterone helps build bone mass, but low calcium levels and estrogen deficiency (as seen in disordered eating and eating disorder patients) in females lead to low peak bone mass and increased bone fragility (i.e., increased risk of stress fractures). Prepubertal gender differences are virtually nonexistent; adolescent pubertal stages correlate to accelerated gains in BMD. Failure to attain adequate peak bone mass is a major risk factor in the development of osteoporosis as well as the rate of bone loss. Regular weight-bearing exercise promotes the development of peak bone mass but cannot compensate for chronic calcium, estrogen, or vitamin D deficiencies. It is generally accepted that low bone density and subsequent osteoporosis can be prevented with proper education and good dietary habits; however, this must be accomplished in the adolescent years. Once a skeletally mature young woman has reached peak bone density, she can only maintain or lose it throughout the rest of her life. It is extremely difficult to see improvements in BMD in adult women despite adequate calcium and vitamin D intake, weight-bearing exercise, and even medications or estrogen supplementation. It is estimated that more than 2 million osteoporotic fractures occur each year in the United States. The number of fragility fractures in athletes resulting from low bone density is not known.

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See also Dietitian/Sports Nutritionist; Nutrition and Hydration; Pregame Meal

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Calf Strain

A common athletic injury, *calf strain* involves a tear in the muscles of the lower leg or calf. With appropriate treatment, the strain usually heals well on its own. Occasionally, severe strain can lead to complications, resulting in chronic symptoms or surgery. Calf strain is seen most often in active adults who engage in sports that require quick starts, stops, and changes in direction.

Anatomy

The calf muscle is actually three separate muscles: the gastrocnemius, soleus, and plantaris. Each muscle has a different origin around the knee, but they all unite in the posterior (back) ankle to form the Achilles tendon. The Achilles tendon then inserts onto the heel just below the ankle joint. The calf muscles plantarflex the ankle (point the toes).

The *gastrocnemius* begins above the knee on the femur (upper leg bone) and is a powerful muscle used for sprinting and jumping. The *soleus* starts below the knee on the tibia (large lower leg bone) and is more of an endurance muscle used for prolonged repetitive motions such as walking or running. The *plantaris* is a small, almost vestigial muscle that begins above the knee. It contributes little to movement but can sometimes become injured and symptomatic.

Causes

Like the fraying of a rope under tension, calf strains are caused by a tearing of the muscle due to the application of a force across the muscle that is greater than the muscle can withstand. The degree of muscle tearing depends on the force applied and the strength of the muscle to withstand that force. Like a braided rope, the thicker the rope, the greater the strength, but at some point if enough force is placed across the rope, it will begin to fail. First, some strands will fray, weakening the rope, and eventually the entire rope will fail.

Calf strains most commonly occur in the medial (inside) aspect of the gastrocnemius muscle. This injury is often called "tennis leg" because it was first described in the late 1800s in conjunction with lawn tennis. The gastrocnemius is at high risk for strain because it crosses two joints (allowing for greater stretch of the muscle across two fulcrums), and it has a high density of Type 2 muscle fiber (fast twitch), which allow the muscle to generate a quick, powerful contraction. This combination of stretching the muscle and then contracting it quickly is similar to the action of a whip and leads to high degrees of force across the muscle and risks muscle strain. For this reason, calf strains have historically been given the moniker of *coup de fouet,* or snap of the whip.

Strains of the soleus are less common. The soleus begins below the knee and crosses only the ankle. The soleus is predominately made up of Type 1 muscle fiber (slow twitch). These factors make the soleus at low risk for strain.

Symptoms

Symptoms of calf strain should be unilateral. They should localize to the calf or posterior knee. The symptom onset should correlate to an injury or activity. They should be reproducible on muscle testing during the physical exam.

Strains of the gastrocnemius are often quite dramatic. They usually occur during a sporting activity immediately following a quick powerful striating of the knee with the foot on the ground and the ankle bent (dorsiflexed). Injury often results in immediate pain and disability. Significant swelling and bruising occur over a period of hours. Patients may experience a tearing sensation. They will find it difficult to walk, and they may adopt a flexed hip and knee position with little ankle movement. Pain is usually localized to the inside of the calf about halfway up the leg.

Strains of the soleus are less striking. They often present weeks after the injury. Patients will complain of ongoing calf tightness, stiffness, and pain associated with running or walking. Swelling and bruising are usually subtle if present. Pain is often localized to the outside of the lower leg (lateral).

Strains of the plantaris present similarly to gastrocnemius strains. However, due to the small size of the muscle and its limited role in knee and ankle function, symptoms will be relatively milder. Plantaris strains usually localize to the lateral (outer) aspect of the calf, close to the knee.

Diagnosis

Calf strains can typically be diagnosed through the history and physical exam. When the diagnosis is in doubt or additional information is needed to guide recommendation for rehabilitation and return to play, imaging such as a magnetic resonance imaging (MRI) scan or an ultrasound may be ordered.

When the symptoms suggest calf strain, a focused physical exam is the first step toward making a diagnosis. Circumferential measurements should be made of each calf if asymmetry is in doubt. The calf should be palpated along its entire length, making note of localized tenderness, swelling, defects, and masses. The physical exam can also be helpful in isolating the calf muscles that have been injured. With the knee fully flexed, the soleus is relatively isolated in testing calf muscle strength, range of motion, and symptom re-creation. The gastrocnemius can be relatively isolated by repeating this testing with the knee fully extended (or straight). More subtle symptoms can often be elicited by re-creating function movements such as running, calf raises, or single-leg hopping. If tolerated, a Thompson test can be performed by squeezing the calf and observing for passive plantarflexion of the ankle; this test is used to help rule out complete rupture of the Achilles tendon.

Calf strains are classified by the muscle injured and the degree of injury. The degree of injury is correlated with a three-part scale based on function, physical exam finding, and amount of tissue damaged. Grade 1 strains are mild, usually allow continuation of activity, and show localized tenderness and swelling on exam but normal strength and range of motion. Grade 1 strains correspond to an injury of less than 10% of the muscle. Grade 2 strains are moderate, preventing normal activity and showing loss of strength and range of motion on exam. Grade 2 strains correspond to an injury of 10% to 50% of the muscle. Grade 3 strains result in immediate severe pain and disability, loss of muscle function, and clear, palpable defect on exam. Grade 3 strains correspond to an injury of 50% to 100% of the muscle.

Treatment

Early appropriate treatment can significantly decrease the duration and amount of disability. Complete recovery of strength and flexibility should be achieved prior to return to full activity. Premature return may cause prolonged or recurrent symptoms. The vast majority of calf strains are treated nonsurgically.

Immediate treatment is aimed at limiting bleeding, reducing pain, and preventing complications. Over the first 3 to 5 days, the muscle is rested by placing it in a relaxed position and avoiding movement. This can be accomplished by placing a wedge under the heel and using crutches to assist in walking. Regular ice should be applied to the injured area for 20 minutes every hour, which provides pain relief and limits swelling and bleeding. Use of a compressive wrap helps immobilize the muscle and aids in reduction of swelling and bleeding. Avoid use of nonsteroidal anti-inflammatory drugs such as aspirin, ibuprofen, and naprosyn in the first 24 to 72 hours, due to the risk of increased bleeding in the injured muscle. Acetaminophen (Tylenol®) or narcotic pain medication is frequently prescribed. Moist heat and massage early in the healing process are believed to increase the chance of hemorrhage and are generally discouraged.

Although rare, myositis ossificans and compartment syndrome can complicate acute strains. If symptoms worsen despite appropriate treatment, prompt reexamination should be done to assess for these complications.

Following successful acute treatment, rehabilitation can be started. Rehabilitative exercises should isolate the specific muscle injured. A rehabilitation program should have a logical progression from passive stretching and range-of-motion exercises to strengthening. Ten days after the injury, if the developing scar has the same tensile strength as the adjacent muscle, further progression of exercises can begin. Isometric, isotonic, and then dynamic training exercises can be added in a consecutive manner as each type of exercise is completed without pain. The addition of physical therapy modalities, including massage, ultrasound, and electrical stimulation, could also be considered at this stage.

Surgery

Surgical consultation should be considered for Grade 3 strains (50–100% disruption of muscle) and for cases of prolonged (4–6 months) pain with evidence of fixed muscle contracture. Contractures suggest the presence of painful and restrictive adhesions within the calf that may be amenable to surgical intervention. The presence of a very large intramuscular hematoma may impair clinical progress and is also an indication for surgical referral.

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See also Achilles Tendon Rupture; Compartment Syndrome, Anterior

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Calluses

A *callus* is a broad-based, thickened patch of skin that forms in response to repeated pressure or friction forces, often a consequence of excessive weight bearing or frequent rubbing of the skin by footwear. It is an accumulation of dead skin cells at the surface layer of the skin that harden and thicken to protect the body. This thickening is called *hyperkeratosis*. Calluses can form over any bony prominence, though they are typically found on the palms of the hands and soles of the feet. The ball of the foot, the heel, and the underside of the big toe are commonly affected. Calluses are generally not harmful or painful and are also referred to as a *tyloma* or a *clavus*.

Causes

A wide variety of factors may lead to the development of a callus.

- Extrinsic factors include poorly fitting footwear (such as shoes that are too tight or have a small toe box), walking barefoot, thin-soled shoes, high heels, thick socks or socks with seams by the toes, prolonged standing, and repetitive activity (i.e., athletics, manual labor). Athletes develop calluses due to repetitive motion and recurrent pressure on the same spot. For instance, cyclists develop calluses on their palms from holding the handlebar grips. Rowers form calluses on several areas of the hand due to friction between the oar and the hand. Runners develop foot calluses from repetitive pounding on hard road surfaces. Dancers and gymnasts develop calluses on their feet from distinctive weight-bearing positions. Wrestlers can have knee calluses from pressure exerted on the mat. Surfers who paddle on their knees develop large, calcified calluses ("surf knots") on their knees.
- Intrinsic factors include foot deformities (high-arched feet, claw toe, hammer toe, mallet toe, short first metatarsal, bunions, malalignment of the metatarsal bones, flat feet, loss of fat pad on the underside of the foot, malunion of fracture), poor foot mechanics or abnormal gait, and obesity.

Presentation

A callus presents as a broad-based, diffuse area of hard growth with relatively even thickness, usually at the ball of the foot. It lacks a distinct border. The affected skin is rough and discolored and can vary in color from white to gray-yellow or brown. Calluses are more common in women than in men.

Calluses are often painless and can actually be advantageous to some athletes. Boxers and martial artists build up calluses on their hands to become more resistant to pain from impact. Dancers develop calluses from dancing barefoot, and yet the calluses can facilitate performing turns. Although typically benign, pressure or friction can precipitate pain. Discomfort, for foot calluses specifically, is amplified by thin-soled and high-heeled shoes. Relief comes with rest.

Some calluses develop a deep-seated core known as a *nucleation*, and patients will complain of pain when pressure is applied. This type of callus is referred to as *intractable plantar keratosis*.

Making the Diagnosis

Calluses are diagnosed based on findings on clinical exam. The location and characteristics of lesions are noted, and the affected area is palpated to feel for a prominent bone underneath the skin surface. X-rays may be done to look at the underlying bony structures that may be the cause of calluses.

Clinicians assess for any contributing factors, such as footwear, repetitive activities, medical history, and previous surgery. Foot mechanics are evaluated by observing a patient's gait. It is important to look for the underlying source of increased mechanical stress on the affected body part in order to construct an effective management plan.

Other conditions that can resemble calluses include warts, tumors of the skin and subcutaneous tissues, and a reaction to a foreign body embedded in the skin (e.g., a wood sliver or piece of glass). Genetic and metabolic disorders of the skin can also cause skin thickening, which can be mistaken for a callus.

Treatment

Recent literature suggests that the principles of callus treatment are four-fold: (1) relieve symptoms; (2) determine the underlying cause of mechanical stress; (3) construct a conservative management plan, including counseling regarding proper footwear; and (4) consider surgery if there is no improvement with conservative measures.

Self-Care

Preventive care for calluses includes avoiding high-heeled and thin-soled shoes. It is recommended that patients wear shoes with good arch support and a shock-absorbing rubber sole. An insole that absorbs shear forces inside the shoe can also reduce the risk of developing a callus and the discomfort that occurs after callus formation.

Protective and palliative care includes moisturizing and padding callused skin. Regular moisturizer use is important for keeping callused skin moist and supple. Moisturizer should be applied at least twice a day. Warm-water soaks are also effective for softening the skin. Epsom salts and essential oils can be added for additional benefit. Once the skin is softened, a pumice stone or foot file can be used to gently file away at the callus, lifting the dead skin and stimulating fresh growth underneath. Caution must be exercised, however, when trying to trim or shave off callused skin on one's own with scissors or sharp blades. This should only be done by clinicians due to the risk of injury and subsequent infection, particularly in people with reduced peripheral sensation, such as diabetics with neuropathy. Nonmedicated pads can be applied around a callus to relieve pressure. It is best to start with a thin pad and gradually build it up to one's comfort. Moleskin pads can also be applied to areas that tend to callus to prevent friction and pressure.

Clinical Interventions

Clinical interventions include topical medications, orthotics, debridement, and surgical correction of a deformity or bony prominence.

Orthotics may be used to change foot mechanics by correcting functional problems and/or redistributing body weight. The goal of orthotics, like various other therapies for calluses, is to reduce pressure and friction and allow the skin to rest. Orthotics should be made with shock-absorbing materials and materials that reduce shearing in the shoe. Nonmedicated pads or moleskin can also be applied around or over the callus, respectively, to relieve pressure.

Debridement (shaving down) of the callus helps even out the skin surface and reduce thickening and abnormal pressure distribution. A small amount of callus is left to provide the bony area with some padding. Keratinolytic medications are used topically on calluses and facilitate debridement. They help reduce a callus by causing the skin to swell, soften, crumble, and then flake away. Examples of keratolytics include urea, alpha-hydroxy acids (lactic acid, glycolic acid), and beta-hydroxy acids (salicylic acid). However, complications can arise if a foot callus becomes too large. There is a risk of it beginning to move with the shoe rather than with the foot, with consequent blister formation. This is detrimental to athletic performance because the blister is difficult to drain.

In cases resistant to conservative measures, surgical correction of a deformity may be necessary. Examples include surgical realignment of the metatarsal bones and removal of bony prominences. Risks of an invasive treatment include infection as well as formation of scar tissue.

Stacy Frye

See also Athletic Shoe Selection; Foot Injuries; Orthotics; Podiatric Sports Medicine

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Cannabinoids

Cannabinoids are substances that come from the plant *Cannabis sativa* and are among the most commonly used illegal drugs around the world. The drug is also known as *marijuana* or *ganja*. Marijuana does not have any known performance-enhancing effects for athletes, but its use is banned in and out of competition.

The psychoactive chemical in cannabis is THC (delta-9-tetrahydrocannabinol). There are dozens of colorful slang terms for marijuana, ranging from common terms such as *weed* or *pot* to references to the amounts that are sold or how much it costs. References used in buying marijuana can be interesting and obscure. One might hear someone asking how much a certain piece of clothing costs when talking in code about buying drugs. A "shirt" might refer to ⅛ ounce (oz; 3.5 gram [g]), whereas "pants" are ¼ oz (7 g), and a "jacket" is 1 oz (28 g). Another popular code is any number of references to "420," which is rumored to have come from the legend of a group of kids in California in the 1970s who smoked marijuana every day at 4:20 p.m.

Cannabis can be prepared into a concentrated resin (hashish) and smoked, vaporized, or ingested (alone or baked and cooked into food products). Usually, however, the dried leaves of the plant are smoked in a pipe or a rolled cigarette. It is typically used as a recreational drug, but there are some medical applications. Accepted medical use includes preparations of THC to stimulate appetite and relieve nausea in patients receiving chemotherapy. Marijuana has also been used to treat conditions such as chronic pain and glaucoma. Medical use of cannabis remain controversial, in part because of the suspicion that many people who are using the drug under the guise of medical treatment do not have the condition that they claim or could do well enough with other, more traditional treatments.

Research has not indicated that users develop a strong physical dependence on cannabinoids, and there are no significant physical withdrawal symptoms once they are stopped. There can be psychological dependence, however. In addition, chronic users may incur significant health risks, particularly from the effects of smoke inhalation, beyond the threat of consequences from law enforcement. For most major sports, including Olympic sports, drug testing panels include a test for cannabinoids. A positive test in competition will result in disqualification and possibly other sanctions. Cannabis is fat soluble and may be detected by modern tests for up to 4 weeks after use.

Side effects can include difficulty in concentrating, impaired motor skills, dry mouth, and depression or apathy. In addition, smoking the drug can cause cough, impair lung capacity, and contribute to cancer. Panic attacks, paranoia, and anxiety are common side effects while the drug is being used.

Over the past three decades, marijuana has been cultivated to make it much more potent. In addition, as with any illicit drug, the purity of each dose cannot be guaranteed. Unexpected exposure to drugs such as phencyclidine (PCP; aka Angel Dust) or gamma hydroxybutyrate (GHB; a date rape drug) when smoking or ingesting marijuana has been reported.

Michael O'Brien

See also Doping and Performance Enhancement: A New Definition; Doping and Performance Enhancement: Historical Overview; Doping and Performance Enhancement: Olympic Games From 2004 to 2008; World Anti-Doping Agency; Young Athlete

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Marijuana-Info.org: http://www.marijuana-info.org

Carbohydrates in the Athlete's Diet

Carbohydrates (CHOs) are the most important source of energy in a balanced daily diet. Carbohydrate intake must be balanced with adequate amounts of protein, fat, and water intake.

In athletes, carbohydrates are the primary fuel source to maintain blood glucose for energy during exercise. Adequate carbohydrate intake also helps spare muscle from catabolic activity and muscle breakdown. After carbohydrates are ingested, they are broken down into smaller sugars (glucose, fructose, and galactose) that get absorbed and used as energy. The body is capable of storing excess carbohydrates in the form of glycogen in the muscles and liver. The body's glycogen capacity is approximately 300 to 400 grams (g). Subsequent excesses are then converted to fat and stored. Conversely, in the setting of inadequate intake, an energy imbalance can result with adverse affects on athletic performance as well as overall health.

Simple Versus Complex Carbohydrates

One gram of carbohydrate provides 4 calories (cal; 16.75 joules [J]) of energy. General guidelines recommend that 6 to 10 g of CHOs per kilogram (kg) of body weight be consumed daily by both adult and adolescent athletes. However, additional recommendations suggest that an adult athlete's diet consist of 60% to 65% CHOs, whereas an adolescent athlete's diet should have 55% to 60% CHOs. Carbohydrates are divided into simple (monosaccharides) and complex (polysaccharides) types. Simple sugars are absorbed and converted to energy very quickly and provide a rapid source of energy. Fruit, 100% natural fruit juice, and sports drinks are good sources of simple carbohydrates. The rise in blood glucose levels is indicated by a food's glycemic index (GI), and the faster and higher the blood glucose rises, the higher the GI will be. A limit of dietary intake of simple sugars is recommended. It is more beneficial to consume lower GI (complex) carbohydrates. Complex carbohydrates take longer to be broken down and absorbed and, therefore, provide energy at a slower rate than simple sugars. Breads, rice, and pasta are common examples of complex carbohydrates. Starch and fiber are also considered complex carbohydrates; however, fiber cannot be digested or used for energy. The most important CHO energy source in an athlete's diet is starch because it is broken down and stored as glycogen. Foods high in starch include whole grain breads, cereals, pasta, and grains (Table 1).

How Important Is Glycogen?

Glycogen is the source of energy most often used for exercise. It can be released up to three times faster than energy from any other source and, therefore, needs to be readily accessible. During training and competition, an athlete's glycogen stores are depleted. To replenish them, the athlete needs to consider the speed at which carbohydrate is converted into blood glucose and transported to the muscles. An intake of between 30 and 60 g of carbohydrate an hour is recommended to maximize the amount muscles can adsorb from the bloodstream during exercise. Greater amounts have no further benefit. During high intensity exercise, carbohydrates are the main fuel for the muscles. Glycogen stores will be kept well stocked if high levels of carbohydrate are consumed before, during prolonged exercise, and after training in the immediate postexercise period.

Athletic performance is limited by the availability of blood glucose and glycogen. It is needed for any short, intense bouts of exercise from sprinting to weight lifting because it is immediately accessible. Glycogen also supplies energy during the first few minutes of any sport. During long, slow-duration exercise, fat (and protein) can help fuel activity, but glycogen is still needed to help break down the fat into energy substrate (Table 2).

Athletes often talk about carbohydrate loading and carbohydrate depletion, which refers to the amount of carbohydrate energy we can store in our muscles. This is generally around 2,000 carbohydrate calories, but we can change this number through depletion and loading. During depletion (from diet, exercise, or a combination of both), we use up the stored carbohydrate. If we don't replenish these stores, we can run out of fuel for immediate exercise. Carbohydrate loading is an attempt to increase CHO stores by eating large amounts of carbohydrates. Our maximal carbohydrate storage is approximately 15 g/kg of body weight. So a 175-pound (79 kg) athlete could store up to 1,200 g of carbohydrate (4,800 cal or 20,096.64 J); enough energy to fuel high-intensity exercise for quite some time.

How Is Energy Created During Exercise?

Anaerobic Metabolism

It is necessary to continually create adenosine triphosphate (ATP) during exercise, both aerobically and anaerobically. The ATP-CP (adenosine

Table 1 Carbohydrate Content in Common Foods

Food	*Amount*	*CHO (g)*
O-shaped cereal, corn pops	1 cup	23–28
Oatmeal	1 cup	26
Bagel	2 oz	31
Granola, low fat	1 cup	82
Graham crackers	2 squares	11
Popcorn	1 cup	6
Pretzels	1 oz	21
Raisins	½ cup	62
Apple	Medium	21
Banana	Medium	27
Orange	Medium	16
Orange juice	½ cup	12
Soda	8 oz	27
Sports drink	8 oz	14
Rice	1 cup cooked	50
Spaghetti	1 cup cooked	34
Beans	½ cup	20–24
Yogurt, fruit	8 oz	42
Yogurt frozen	8 oz	34

Note: CHO, carbohydrate; 1 ounce (oz) = 29.57 ml.

Table 2 Recommended CHO Intake Before, During, and After Exercise for an Average Pediatric Athlete and an Adult Athlete

Timing	*Amount of CHO (g/kg body weight)*	*40-kg Athlete (Total CHO/kcal)*	*70-kg Athlete (Total CHO/kcal)*
Pre-exercise (3–4 hours)	4	160 g/640 kcal	280 g/1,120 kcal
Pre-exercise (1–2 hours)	0.5–1	20–40 g/80–160 kcal	35–70 g/140–280 kcal
During exercise	0.7 every 20 minutes after 1 hour of exercise	28 g/112 kcal	49 g/196 kcal
Postexercise	1–1.5	40–60 g/160–240 kcal	70–105 g/280–420 kcal

Note: 1 kilocalorie (kcal) = 4,200 joules.

triphosphate–creatine phosphate) energy pathway supplies about 10 seconds worth of energy used in short bursts or in sprints. It uses ATP stored in muscle and then uses CP to resynthesize ATP until CP is used up. Then the body must use another pathway to create energy.

Glycolysis is the second anaerobic energy pathway that creates ATP exclusively from carbohydrates and creates lactic acid as a by-product. Glycolysis provides energy through the partial breakdown of glucose and is best for short, high-intensity bursts of exercise. Lactic acid builds up quickly, resulting in muscle pain, burning, and fatigue that reaches a certain threshold and results in cessation of exercise.

Aerobic Metabolism

Aerobic metabolism fuels most of the energy needed for long-duration activity. It uses oxygen to convert nutrients (carbohydrates, fats, and protein) to ATP. This system is slower than the anaerobic systems because it relies on the circulatory system to transport oxygen to the working muscles before it creates ATP. Aerobic metabolism is used primarily during endurance exercise. Fat is a great fuel for endurance events, but it is simply not adequate for high-intensity exercises such as sprints or intervals. If you are exercising at a low intensity (or below 50% of max heart rate), you have enough stored fat to fuel activity for hours or even days as long as there is sufficient oxygen to allow fat metabolism to occur. A balanced diet of CHO, protein, and fat provides enough substrate for the body to use both anaerobic and aerobic metabolism efficiently in the appropriate exercise setting.

What Is the Ideal Precompetition Meal?

Precompetition meals are essential to maintain energy levels during sustained exercise. Consuming 1 to 4.5 g of CHO/kg of body weight 1 to 4 hours preactivity is ideal for maintaining blood glucose levels during exercise by ensuring adequate CHO availability. The meal composition should be relatively high CHO, low fat, and limited protein. The GI of foods also affects athletic performance. High-GI foods may cause a rapid increase in serum blood glucose, which in turn triggers an insulin response to counteract the rapid glucose rise. Conversely, low-GI foods provide sustained energy release without rapid increases and decreases in serum blood glucose and energy substrate. Low-GI foods include whole grain products, vegetables, beans, milk, low-fat yogurt, and some fruits (Table 3).

Table 3 Sample Precompetition Meals

Toast and jelly
Baked potato
Spaghetti with tomato sauce
Cereal with skim milk
Low-fat yogurt with fruit

What Does Our Body Need After Exercise?

It is important to consume carbohydrate within minutes of cessation of exercise to restore glycogen. About 100 to 200 g of CHO within 2 hours of endurance exercise is essential to build adequate glycogen stores. Furthermore, complex carbohydrate ingestion may be preferred, and simple carbohydrate ingestion should be limited. Combining protein with carbohydrate (CHO + AA) in the postexercise meal consumed within 2 hours of cessation of exercise nearly doubles the insulin response. As a result, a significantly larger amount of glycogen stores are replenished. The ideal carbohydrate to protein ratio is 4:1 g. Excessive protein intake postexercise can slow glycogen replacement and rehydration. Protein intake provides the necessary amino acids to rebuild muscles broken down during intense exercise and improves muscle hydration. Consumption of CHO + AA postexercise improved postexercise recovery, thus, preventing decline in endurance performance heavy exercise bouts in the consecutive day. What research has failed to demonstrate is an actual improvement in exercise performance in endurance athletes following protein or CHO + AA supplementation. Thus, the optimal intake of CHO/protein quantities is likely individual and is affected by personal tolerance, dietary practices, metabolism, and exercise type as well as length. Further research is needed to establish optimal CHO/protein types, amounts, and timing with regard to specific types of exercise.

Conclusion

Sports nutrition is built on an understanding of how nutrients such as carbohydrate, fat, and protein contribute to the fuel supply needed by the body to perform exercise. In athletes, carbohydrates are the primary fuel source to maintain blood glucose for energy during exercise. Adequate carbohydrate intake also helps spare muscle from catabolic activity and muscle breakdown. Energy is used by the body in the form of ATP. Muscle contraction occurs via anaerobic and aerobic metabolism of ATP. Athletes who maintain ideal health and fitness are able to supply the body with adequate carbohydrate before, during, and after exercise. The optimal quantities, types, and timing of CHO, and all nutrients, intake is likely varied among athletes. Dietary intake of CHOs and other nutrients for energy substrate is preferred over commercial supplementation whenever possible.

Holly J. Benjamin

See also Dietitian/Sports Nutritionist; Nutrition and Hydration

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Cardiac Injuries (Commotio Cordis, Myocardial Contusion)

Sudden death in athletes who otherwise appear healthy has often been attributed to an underlying structural or electrical defect in the individual's heart. This is not unjustified, as many sudden deaths in apparently healthy athletes have eventually been linked to an undiagnosed cardiac condition. The medical community and even the media are growing in awareness of several of these cardiac conditions, most notably hypertrophic cardiomyopathy and long QT syndrome. Not surprisingly, vigilant screening aimed at detecting these potentially lethal conditions is part of the standard of care with regard to medical preparticipation exams of athletes.

However, sudden cardiac death in the athlete has also been observed when no previous heart defect was noted. In fact, it is well recognized that blunt, nonpenetrating, and seemingly innocuous blows to the chest may result in sudden death during competitive or even recreational sports activities. *Commotio cordis* (Latin for commotion of the heart) is the term commonly used to describe these cases of sudden cardiac death caused by chest blows. In reality, however, there are a small percentage of cases in which an individual is fortunate enough to survive a commotio cordis event.

Commotio cordis is a cardiac contusion brought about by sudden, nonpenetrating precordial trauma or impact, which causes arrhythmias (ventricular fibrillation [VF]) and, subsequently, sudden cardiac death without any evidence of cardiac injury on autopsy.

Epidemiology

Accurate demographics pertaining to commotio cordis are somewhat limited by the relatively small number of cases compared with other known sports-related disease entities. A lack of recognition of commotio cordis and underreporting are also likely contributing factors. It is considered the second most common cause of sudden cardiac death after hypertrophic cardiomyopathy.

One commonly used source for confirmed cases of commotio cordis is the U.S. Commotio Cordis Registry (Minneapolis, Minnesota). The registry compiles information from a number of sources, including the media and the Internet, the U.S. Consumer Product Safety Commission, and interested medical and nonmedical parties. Based on this registry and as of September 1, 2001, there were 128 confirmed cases of commotio cordis in the United States.

Inclusion criteria in this registry consisted of four items. First, an eye-witnessed event of a blunt, nonpenetrating blow to the chest should immediately precede cardiovascular collapse. Second, detailed documentation of the circumstances should be available. Third, there should be no structural damage to the sternum, ribs, and the heart itself. Finally, there should be no underlying cardiovascular abnormality.

Using these criteria, the registry data revealed that the vast majority of commotio cordis events occurred in young (mean age 13.6 years) males (95% confirmed cases) playing organized sports. The registry showed that 87% of cases occurred in Caucasians. Age of incidence ranged from 3 months to 45 years; however, commotio cordis most frequently occurred in male children from age 4 to 16 years. Only 22% of cases occurred in patients aged 18 or older.

While several sports were represented, baseball, softball, and hockey in descending order accounted for most of the cases. The registry also noted that both fatal and nonfatal events took place, with approximately only one survivor for every five deaths. Additionally, the registry found that commotio cordis events occurred even with protective equipment, including chest protectors and balls specifically designed to reduce risk of injury (Table 1).

Table 1 Causes of Commotio Cordis Injuries in Sports

Causes	*Number*
Sports related	
Baseball	40
Softball	7
Ice hockey	7
Football	3
Soccer	3
Rugby	2
Karate	2
Lacrosse	1
Boxing	1
Other sports	4
Other causes	
Fights	2
Vehicular accidents	3
Child abuse	1

Source: Data from Maron BJ, Gohman TE, Kyle SB, Estes NA, Link MS. Clinical profile and spectrum of commotio cordis. *JAMA*. 2002;287(9):1142–1146.

Pathophysiology

When an electrocardiogram (EKG) could be recorded after a collapse from commotio cordis, the most common arrhythmias were either VF or asystole. It is presumed that individuals dying from commotio cordis typically will sustain trauma-induced VF prior to their death. Two factors play a role in this sequence of events: the timing and hardness of the impact.

The electrophysiologic consequences of chest wall impact depend on the timing of impact during the cardiac cycle. Specifically, based on animal models, it is thought that chest wall trauma delivered during the upstroke of the T wave results in VF. Others believe that trauma-induced precipitation of premature contractions predisposes to eventual VF in commotio cordis.

In a 2001 study published in the *Journal of the American College of Cardiology,* Link et al. used a pig model to demonstrate that impact with a wooden object, convex in shape and weighing 150 grams (reproduction of a regulation baseball), to the precordium, directly over the left ventricle, within the window from 30 to 15 milliseconds (ms) before T wave peak on EKG, produced VF—nine episodes of VF on 10 impacts. This small window represents approximately 3% of the cardiac cycle in individuals whose heart rate is 120 beats per minute. VF was not preceded by ventricular tachycardia, conduction abnormalities, or ST changes on EKG, evidence that the mechanism of injury is secondary to electrical conduction etiology rather than myocardial ischemia. VF was not elicited by impacts during other times in the cardiac cycle.

Seven impacts delivered during the T wave but outside the 30- to 15-ms window before T wave peak resulted in only two episodes of polymorphic ventricular tachycardia.

When 10 impacts were delivered during the QRS complex, 4 resulted in transient complete heart block for up to 7 sinus beats, and with return of sinus rhythm, subjects developed ST elevation and left–bundle-branch block for up to 120 seconds. The other 6 resulted in ST-segment elevation and left–bundle-branch block.

Another pig study by Link et al., in 1998, using baseballs of differing consistencies affecting the precordium at 30 miles/hour (48.28 kilometers/hour). They showed that the force of precordial trauma was inversely related to fatal outcome and the harder the consistency of the baseball, the higher the incidence of VF.

With the softest-consistency baseball, two episodes of VF were elicited in 26 impacts (8%) in 12 animals. With the medium-soft ball, six episodes of VF were elicited on 27 impacts (22%) in 12 animals. With the hard ball, six episodes were elicited with 21 impacts (29%) in 12 animals. Finally, with a regulation baseball, eight episodes were elicited in 23 impacts (35%) in 12 animals.

Chest wall biomechanics should also be taken into account. Younger athletes with narrower anteroposterior diameter of the thorax and increased compliance of the chest are more susceptible to commotio cordis.

In a 2000 study published in *Circulation,* Bode et al. used a rabbit model to elicit VF from sudden myocardial stretch. VF induction was secondary to a rapid rise in left ventricular pressure from impact, with resulting potassium-ATP (adenosine triphosphate) channel activation and subsequently premature ventricular depolarization and development of VF.

History

Commotio cordis occurs typically, as previously stated, in a sport that involves a projectile device. Most cases of commotio cordis fall into two categories of presentation. In one situation, sudden death will occur immediately on impact. In the other, the individual may collapse and then make purposeful movements or gestures prior to death. In the second situation, it is thought that a brief period of a perfusing arrhythmia, such as ventricular tachycardia, may precede VF.

Treatment

We have few data on the benefits of treatment as death occurs in the majority of cases. As of September of 2001, there were two cases of spontaneous resuscitation from presumed aborted commotio cordis. Otherwise, nonfatal commotio cordis events (21 people, or 16%, of all cases through September of 2001) were only observed when prompt cardiopulmonary resuscitation and defibrillation were employed.

Commotio cordis should be treated as a cardiopulmonary emergency. While maintaining airway, initiating oxygenation, and delivering chest compressions, the most critical component in this case is early defibrillation (less than 4 to 8 minutes from the time of collapse). Successful resuscitation relies on early defibrillation. Spontaneous termination of ventricular arrhythmias rarely occurs.

In the pig models, defibrillation within 1 minute of VF resulted in a 100% survival rate, and defibrillation within 2 minutes resulted in an 80% survival rate. Defibrillation at 4 minutes resulted in no survivals, unless cardiopulmonary resuscitation (CPR) was instituted after the defibrillation, which increased survival to 65%.

In general, out-of-hospital defibrillation occurs within 3 minutes of cardiac arrest and produces a survival rate of 50%. Every minute's delay after the initial 3 minutes results in a 10% decrease of survival rate. Emergency medical services usually arrive after 5 minutes of cardiac arrest; therefore, the use of automated external defibrillators (AEDs) may save many lives.

AEDs and their availability is the gold standard of treatment. Until further research can help identify and prevent those at risk for commotio cordis, the paradigm for dealing with commotio cordis is rapid defibrillation. In 2001, AEDs were modified so as to be able to deliver appropriate voltages to children less than 8 years old or weighing less than 55 pounds (24.95 kg).

Prevention

The use of appropriate protective equipment should be encouraged in all age-groups. However, it is known that commotio cordis occurs despite the use of protective gear.

In one study, 38% of athletes who experience commotio cordis had been wearing chest protectors at the time of impact. Of those athletes who experienced commotio cordis after sustaining an impact, 22% were struck by objects directly on their chest protectors, while 78% of the athletes did not have adequate coverage because of migration of chest protectors over the precordial area.

In another swine model, chest protectors were not shown to significantly decrease the incidence of VF from impacts from baseballs and lacrosse balls when compared with controls without chest protectors. This lack of benefit from chest protectors may be due to the poor fit of the protective gear for children of different ages and sizes or the materials used. Moreover, the use of balls with softer cores can provide a similar benefit. Age-appropriate baseballs of diminished hardness should be used for children under the age of 13 years. Whether chest pads or soft-core balls provide adequate protection against commotio cordis is still a matter of debate.

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See also Athlete's Heart Syndrome; Congenital Heart Disease; Pulmonary and Cardiac Infections in Athletes; Sudden Cardiac Death

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Cardiovascular and Respiratory Anatomy and Physiology: Responses to Exercise

The capacity for exercise is the net effect of a synchronized response of the cardiovascular and respiratory systems. Understanding the anatomy and physiology of each system is key to understanding how the systems interface at rest and with exercise.

Anatomy and Physiology

Cardiovascular

The heart is a muscular organ roughly the size of a human fist, which is located slightly left of center beneath the sternum and ribcage within the chest cavity. Its job is to receive deoxygenated blood from the body and pump it to the lungs and to receive oxygenated blood from the lungs and pump it to the body, and the organs and muscles use this supply of oxygen and nutrients to function. The human heart has four chambers (Figure 1): right atria, right ventricle, left atria, and left ventricle. The normal path of blood flow is as follows: Blood flow returns from the body via two large veins, called the superior and

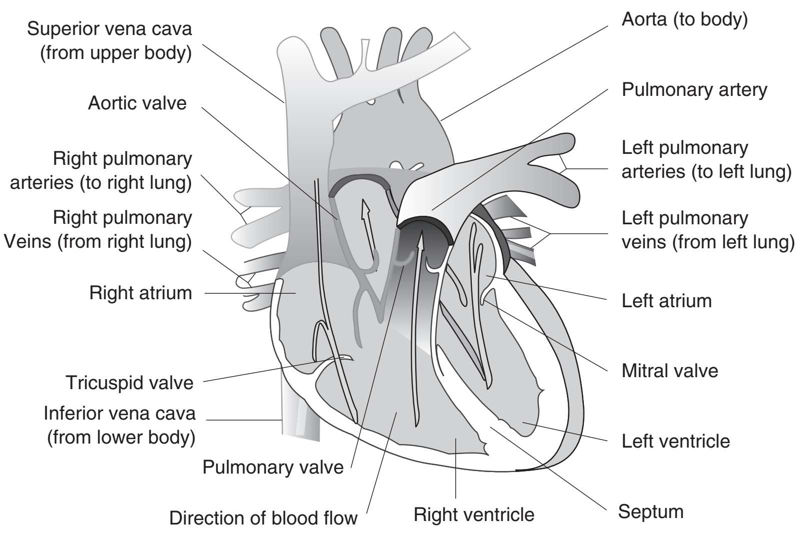

Figure 1 Cardiac Anatomy

inferior vena cava, and collects in the right atria before passing through the tricuspid valve into the right ventricle. It is then pumped through the pulmonary valve into the pulmonary artery, which takes blood into the dense capillary network of the lungs. Here, blood picks up oxygen and releases carbon dioxide before returning via the pulmonary vein to the left atria. From the left atria, blood flows through the mitral valve into the left ventricle before being pumped through the aortic valve into the aorta, a large artery that carries blood away from the heart toward the peripheral organs.

Embedded in the myocardium (heart muscle) is a conducting system that propagates an electrical impulse from its point of origin in the sinoatrial (SA) node in the wall of the right atrium through both atria and ventricles, causing the coordinated, rhythmic muscular contraction that propels blood through vessels as outlined earlier. Pathways involving the parasympathetic and sympathetic nervous systems affect the rate at which the SA node generates an impulse. Parasympathetic activity decreases the heart rate, while sympathetic activity increases it. The actual heart rate is the net effect of these "up and down" messages.

The amount of blood the heart pumps in a minute is known as the cardiac output. The cardiac output is a product of the stroke volume (volume of blood pumped per contraction) and the heart rate (number of times the heart beats per minute). A normal resting heart rate is approximately 70 beats/minute, and a typical stroke volume is approximately 70 milliliters (ml)/minute; thus, a standard reference for cardiac output is roughly 5 liters (L)/minute. Of course, this is just a general reference value, and the actual cardiac output of a specific individual will vary.

Although the heart is the organ responsible for pumping blood, heart muscle also requires oxygenated blood and nutrients. These are supplied via coronary arteries that arise from the aorta.

Respiratory

Within the area bounded by the ribs, sternum, spine, and diaphragm are the lungs (Figure 2). This framework, known as the thorax or thoracic cavity, supports the lungs and helps keep them open; if the lungs were to be removed from the thoracic cavity, they would partially collapse. The right lung has three lobes: the upper, the middle, and the lower. On the left, there are two lobes, the upper and the lower, and a third significant section of the upper lobe, known as the lingula. The lungs are surrounded by a specialized skinlike surface known as the visceral pleura, and the lobes are separated and defined by inflections of the pleura. A similar surface, the parietal pleura, lines the thoracic cavity. During respiration, these two surfaces, lubricated by a small amount of fluid, slide smoothly over each other.

The airways. The nose and the mouth connect to the trachea or windpipe, which branches within the thoracic cavity to the left and right main-stem bronchi. Each main bronchus then divides further into the lobar bronchi, which in turn subdivide for 15 to 20 generations until the smallest conducting airway is reached at the level of the terminal bronchiole. The volume of air in the conducting airways is known as anatomic "dead space" because no gas exchange occurs. This volume is roughly 150 ml in the average adult. The terminal bronchioles then divide further into respiratory bronchioles and alveolar ducts before ending in alveoli. Although some gas exchange can occur at the level of the respiratory bronchiole and alveolar duct, the alveoli are uniquely designed for this purpose. The walls of an average adult's

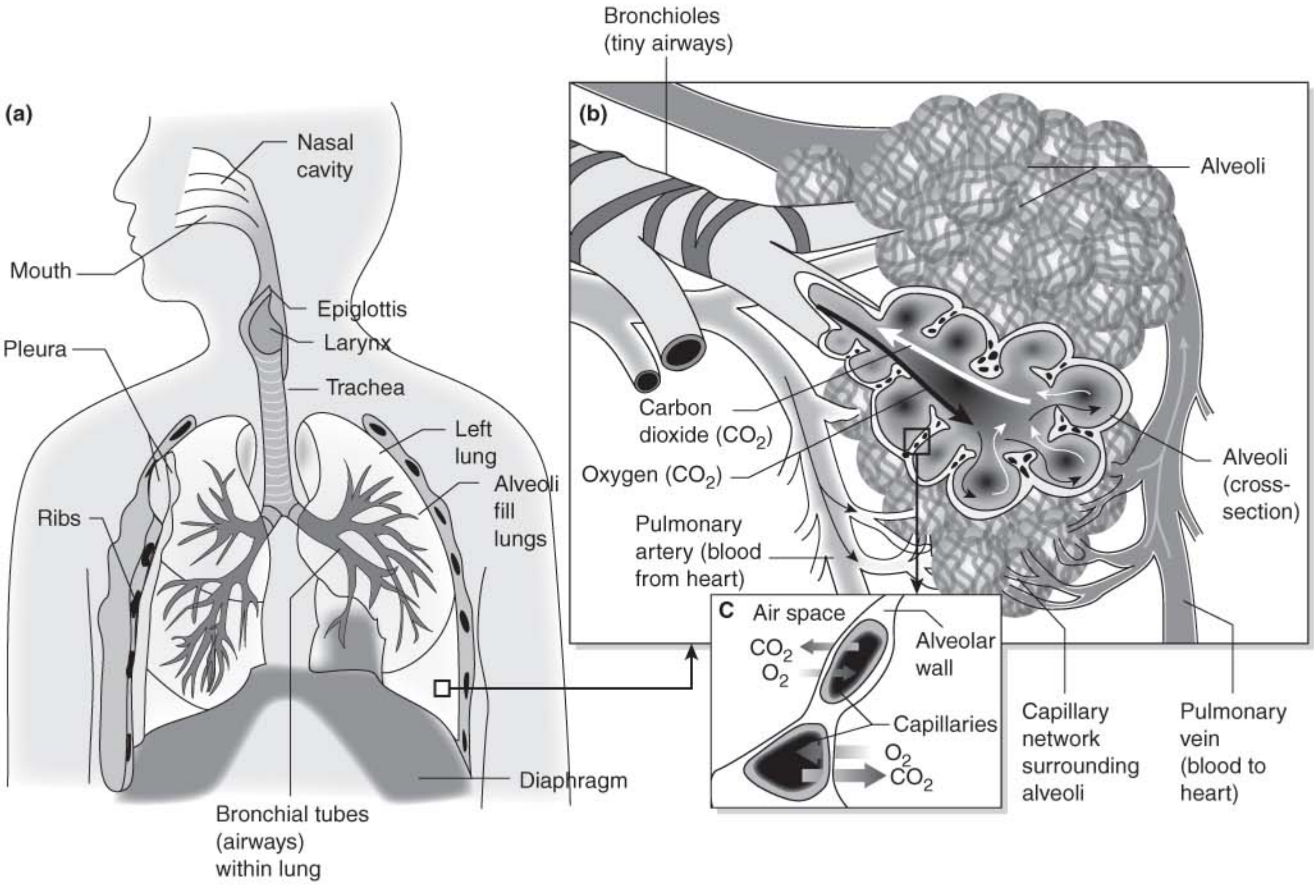

Figure 2 Anatomy of the Lung

300 million alveoli are very thin and surrounded by capillaries, thus creating a surface area approximately equivalent to the size of a tennis court for efficient gas exchange. The volume of each breath is the tidal volume; the maximal volume of air in a single breath is the vital capacity, the amount of air in the alveoli is termed the alveolar volume; and the amount of air available for ventilation in a minute is the minute ventilation. Recall though that in each breath, there is an obligatory 150 ml of dead space. Thus,

$$\text{Minute ventilation} = \text{Breathing frequency} \times (\text{Tidal volume} - \text{Dead space}).$$

The muscles of respiration include the *intercostal muscles* and the *diaphragm*. The intercostals are located between the ribs and contract to move the ribs from their somewhat slanted position to a position more perpendicular to the axis of the spine. The diaphragm is a long flat muscle located at the base of the ribs with attachments to the ribs, xiphoid process, and lumbar spine; it separates the abdominal cavity from the chest cavity. At rest, it has a dome shape, with the convex portion of the dome on the thoracic side of the muscle. With respiration, the diaphragm flattens. The actions of the intercostal muscles to rotate the ribs and the flattening of the diaphragm function to increase intrathoracic volume, which, in turn, creates negative pressure inside the chest cavity and causes air to flow into the lungs. At end inspiration, pressure in the lung is atmospheric, and the driving force for air movement is satisfied. To initiate exhalation, the intercostals and the diaphragm relax. Their movement toward their natural resting position increases the intrathoracic pressure, causing air to be expelled from the lungs. It is important to note that at rest, exhalation is a passive process.

The lung has two networks of blood vessels: the *bronchial* circulation and the *pulmonary* circulation. The bronchial vessels arise from the aorta and bring oxygenated blood and nutrients to the lung tissue, while the pulmonary vessels carry blood to and from the heart for gas exchange. Blood flow through the pulmonary vessels is not uniform. Instead, it is stratified as a result of gravity such that the base of the lung receives the most blood flow and the apex receives the least.

Exercise

Exercising muscle demands a greater supply of oxygen to meet the needs of increased aerobic work. The respiratory and cardiovascular systems are remarkably well equipped to quickly and efficiently respond to this demand.

Cardiovascular

Heart rate increases during exercise as the result of an increase in sympathetic input and a decrease in parasympathetic input. In fact, just thinking about exercise will increase your heart rate, priming you for activity. Cardiac filling and ejection fraction also increase, thus cardiac output also increases, which improves the blood supply to the exercising muscle. The amount of cardiac output that a given subject is capable of producing is the result of a combination of genetics and training. Endurance athletes, for example, may increase their cardiac output to as much as 30 to 40 L. As subjects approach their maximal heart rate, there is less time between contractions for the heart to fill with blood. Reduced ventricular filling time limits increases in stroke volume, and increasing cardiac output becomes dependent on heart rate.

Peripherally, there is also vasodilatation of the vascular beds in the working muscles, as well as vasoconstriction in other organs, such that a greater percentage of the cardiac output is directed toward the exercising muscle. At rest, only about 15% of the cardiac output is directed to muscle; however, with intense aerobic exercise in trained athletes, muscles may receive as much as 60% to 70% of the cardiac output.

Respiratory

This increase in cardiac output also requires the lungs to accommodate markedly increased blood flow. Fortunately, with exercise, pulmonary vessels dilate and distend, resulting in a decline in vascular resistance. This enables the lung to accept the increased blood volume pumped by the heart without significantly increasing pulmonary vascular pressure or sacrificing gas exchange.

During exercise, minute ventilation increases due to an increase in both tidal volume and respiratory rate. With intense exercise, tidal volume may be up to 70% of the vital capacity. Respiratory rate, which was ±12 at rest, can be as high as 55 in healthy adults and >60 in children. Accessory muscles of respiration, including the abdominal, neck, and other chest wall muscles, are recruited during both inspiration and expiration. Exhalation, which was passive at rest, becomes an active process.

With exercise, carbon dioxide production increases in working muscle. However, the rise in ventilation is well matched to metabolic demand, and as a result, arterial carbon dioxide levels remain constant. Oxygen saturation also typically remains constant; however, highly trained athletes may desaturate during exercise as a result of ventilation/perfusion mismatch and diffusion limitation.

While the human body is capable of responding rapidly to increased work demands, this capacity is not unlimited. Typically, at maximal exercise, individuals are limited by cardiovascular capacity. Although training will improve the capacity to pump blood to the working muscles, ultimately, training cannot completely overcome this limitation, and most athletes remain cardiovascularly limited and have a respiratory reserve at maximal exercise.

Dawn Ericson

See also Athlete's Heart Syndrome; Congenital Heart Disease; Pulmonary and Cardiac Infections in Athletes; Sudden Cardiac Death

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Careers in Sports Medicine

The athlete is at the center of the sports medicine environment. Athletic success may be measured by wins and losses, individual or team championships, or merely active participation. The professionals who serve athletes should have the health, safety, and participation success of athletes as their priority.

Certified Athletic Trainer

The certified athletic trainer (ATC) may be described as the "hub of the wheel" in the treatment of competitive athletes. The ATC works with the athlete on a daily basis and is often the link between the athlete and the physician, coaching staff, physical therapist, and media.

Certification for an athletic trainer includes earning a bachelor's or master's degree from an accredited athletic training curriculum. Formal training in injury/illness prevention, emergency and first aid, triage of injury/illness, therapeutic modalities, rehabilitation, and return-to-play decisions are part of the athletic trainer's educational background. Close to 70% of athletic trainers have a master's or a doctoral degree.

Physician

Physicians play a crucial role in the treatment of athletes and in assisting them in accomplishing their athletic goals. Physicians from any branch of medicine may be important in the athlete's life, but primary care and orthopedic surgeons are the main contributors. Physicians may complete their education in an allopathic (MD) or osteopathic (DO) medical school.

Primary Care

Primary care team physicians come from the specialties of family medicine, internal medicine, pediatrics, emergency medicine, and physical medicine and rehabilitation. At the intercollegiate and professional levels, the primary care team physicians, in collaboration with the athletic training staff, coordinate preparticipation physical exams and care for general medical issues and nonsurgical musculoskeletal injuries. Often, the primary care team physician evaluates the injuries and illness triaged by the athletic training staff, treats those in his or her specialty, and coordinates referral to the orthopedic surgeon or sports medicine advisory staff.

Completion of a primary care sports medicine fellowship and obtaining a Certification of Added Qualifications in Sports Medicine along with clinical experience distinguishes the physician as one qualified to appropriately treat athletes.

Family Medicine

Family physicians treat the total health of the individual and family primarily in an outpatient setting. Family practitioners receive training in internal medicine, pediatrics, surgery, obstetrics and gynecology, and electives in many other medical specialties.

Internal Medicine

Internists primarily treat older adults. They are trained to diagnose and care for severe chronic illnesses and conditions in which several illnesses occur at the same time. Internists do much of their work in hospitals because of the severity of their patients' illnesses.

Pediatrics

Pediatricians diagnose and treat conditions in infants, children, and adolescents. Many pediatricians limit their practice to treating 14- to 18-year-olds.

Emergency Medicine

Emergency medicine physicians diagnose and treat acute illnesses and injuries that need immediate medical attention. They are competent in a variety of medical fields and are educated in numerous procedural skills to stabilize patients for further care. They treat most of their patients in hospital emergency rooms.

Physical Medicine and Rehabilitation

Physiatrists are physicians who treat disability caused by sports injury, spinal cord injury, brain injury, or other conditions causing pain. They restore function by designing treatment strategies through the combined use of medications, physical modalities, electrodiagnostics, physical training with therapeutic exercise, modification of movement and activities, adaptive equipment and assistive devices, orthotics (braces), prostheses, and experiential training approaches.

Orthopedic Surgery

Orthopedists are surgeons who specialize in the musculoskeletal system. Many orthopedists elect to subspecialize in a branch of orthopedic surgery, such as surgical sports medicine, hand surgery, shoulder and ankle surgery, foot and ankle surgery, pediatric orthopedics, orthopedic trauma, or total joint reconstruction.

Sports Medicine Advisory Team

Many sports organizations use a "sports medicine advisory team," though the terminology may differ depending on the institution. This is a group of physicians chosen by the primary members of the sports medicine team (athletic trainer, primary care team physician, and orthopedic surgeon). It comprises physicians who provide expertise beyond the specialties of the primary members. This includes dentists, cardiologists, pulmonologists, gastroenterologists, neurologists, neurosurgeons, and radiologists, among others. Because of the urgency to return athletes to the field of play, these individuals agree to see athletes on a timely basis and communicate promptly to the health care team.

Undergraduate and medical school, residency and fellowship training, and specialty certification examinations all provide the educational foundation for physicians and allied health professionals, but experience in the treatment of athletes is the most important factor in successful sports medicine care.

Other Allied Health Professionals

Physical Therapists

Physical therapy or "physiotherapy" is the specialty that uses functional movement to restore health. This includes range of motion, strength, balance, proprioception, joint mobilization and manipulation, neuromuscular reeducation, therapeutic exercise, and use of modalities to prevent, treat, or rehabilitate injury.

Chiropractors

Chiropractors are health care professionals who diagnose and treat mechanical disorders of the musculoskeletal system, with special emphasis on the spine. They use manual therapy, soft tissue and spinal manipulation, exercise, and lifestyle counseling without the use of medicine or surgery.

Sport Psychologists

Sport psychologists use mental factors to manage emotions and increase performance or overcome poor performance. The skills used include relaxation, goal setting, self-awareness, concentration, control, relaxation, self-talk, and use of rituals.

Nurse Practitioners

Nurse practitioners (NPs) are registered nurses who have completed advanced nursing education and training to diagnose, manage, and treat medical conditions. Generally, they have completed a master's degree. Many are certified in specialty care. They can practice independently or in conjunction with a physician.

Physician's Assistants

Physician's assistants (PAs) are clinical practitioners who practice medicine under the supervision of a licensed physician. PA school is 2 to 3 years in duration, as opposed to the traditional 4 years of medical school. In addition, PAs are not required to do a residency like physicians are.

Medical Assistants

Medical assistants (MAs) are health care workers who perform clinical or administrative functions in the office of a health care professional. They are not licensed to treat patients but often assist the physician in coordinating the care of the patient. They receive their formal education in vocational schools, technical institutes, or community colleges or through online educational programs.

Nutritionists and Dietitians

Sports nutritionists assist athletes with regard to diet and nutrition. Whereas special licensing is not required to provide nutritional advice, dietitians are professionals who have passed an exam and have completed strict criteria to be registered with the American Dietetic Association. Athletes require nutritional balance to perform at their best; this involves optimal caloric intake, correction of nutritional deficits, and nutrient manipulation.

Radiologic Technologists

Radiographers are health care professionals who create medical images of the body to assist the health care providers in diagnosis of and treatment of injury and illness. Examples include diagnostic radiography (X-ray), ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), and nuclear medicine.

Exercise Physiologists

Exercise physiology is a health care discipline that studies how exercise affects the function and structure of the human body. Exercise physiologists design physical fitness programs to prevent disease and disability, do exercise testing and cardiac rehabilitation, and are involved in research activities to improve performance.

Brent S. E. Rich

See also Athletic Trainers; Dietitian/Sports Nutritionist; Orthopedist in Sports Medicine, Role of; Sports Biomechanist; Sport and Exercise Psychology

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Carpal Fractures

The *carpal bones* allow the wrist to move and rotate both horizontally and vertically. Within the wrist, these bones form two rows. The most proximal row, which is closest to the forearm, has four bones in it. These bones, starting from the lateral side of the wrist and moving medially, include the scaphoid, lunate, triquetrum, and pisiform. The distal row, which is closest to the metacarpals, includes the trapezium, trapezoid, capitate, and hamate. All have multiple ligaments that attach to them on the front, or palmar surface, and the back, or dorsal surface.

The carpal bones can be fractured from a direct strike or from falling on an outstretched hand. For instance, football linemen can fracture their scaphoid or dislocate their carpal bones when pushing off or against defending players. Patients who sustain carpal fractures often have considerable pain in their wrist and/or hand area. There can be swelling and bruising associated with this injury. Patients may be unwilling to move their wrist or fingers.

If this type of injury is suspected, initial management of the patient is to apply a splint to the affected wrist so that it is immobilized. Ice and elevation of the extremity to the level of the heart or just slightly above often help keep swelling under control. If a carpal fracture is suspected, an X-ray must be obtained.

Specific Types of Carpal Fractures

Scaphoid

In athletes, the carpal bone that is most commonly fractured is the scaphoid. The scaphoid is located on the thumb side of the hand, within the anatomic snuffbox. These fractures most often occur from a fall on an extended wrist, which is not uncommon in soccer and football. Scaphoid fractures are less common in children, but they certainly can occur. Often this fracture does not seem like a serious injury and is initially written off as a wrist sprain. Any tenderness in the anatomic snuffbox, however, should raise suspicion for a scaphoid fracture. If an athlete has been diagnosed with a wrist sprain and does not seem to be getting better, there may be an underlying fracture.

The scaphoid gets its blood supply through ligaments that attach to it. The blood supply is better to the more distal part of the scaphoid. Blood supply to the more proximal part of the scaphoid is precarious, especially after fracture.

If there is a suspicion of scaphoid fracture, then an X-ray of the hand should be performed. Sometimes, even though an athlete has a scaphoid fracture, the X-ray does not initially show the fracture. Any contact sports athlete or any athlete who has sustained a recent fall and is complaining of radial-side wrist pain should be considered to have a scaphoid fracture until studies have proven otherwise. If the initial X-ray does not show a fracture but a scaphoid fracture is suspected from exam, the wrist is still put in a splint to immobilize the suspected fracture. Other imaging modalities that may help diagnose a fracture are computed tomography (CT) and magnetic resonance imaging (MRI).

If a scaphoid fracture is diagnosed, it should initially be immobilized in a thumb spica splint. Either this will need to be transitioned into a thumb spica cast in 1 to 2 weeks, when swelling subsides, or operative intervention may be needed depending on the location of the fracture or how displaced the fracture is within the scaphoid. This decision will ultimately be made by an orthopedic surgeon, and the athlete should be referred to an orthopedic surgeon if a scaphoid fracture is noted.

Lunate

Lunate fractures are rather rare. The lunate is the bone immediately adjacent to the scaphoid. Acute lunate fractures that are displaced often need surgical intervention to decrease the chance of osteonecrosis and make the wrist more stable. Some lunate fractures can be treated in a cast.

Some athletes may develop avascular necrosis of the lunate, presumably from repetitive trauma to the bone. This has more of an insidious onset and does not have to be related to a specific traumatic event. Its treatment depends on the changes to the lunate, but often surgical intervention is needed.

Triquetrum

Triquetral fractures are often associated with other wrist injuries. This fracture usually happens when the wrist twists or rotates forcefully, causing the bone to shear across the surfaces of the other bones in the wrist. This type of fracture can also happen when an athlete falls with the wrist extended, and it occurs often in skaters.

There are different types of triquetral fractures, some of which need surgical intervention and others that can be treated in a cast. Often, CT scans need to be obtained along with X-rays to fully assess the extent of the fracture. The triquetrum can also dislocate, but this is very rare. If the triquetrum is dislocated, it should be reduced in the emergency department by a trained physician.

Pisiform

Fractures of the pisiform are relatively uncommon, representing only 1% of all carpal bone fractures. Most commonly, this fracture occurs when there is a direct blow overlying the pisiform. Sometimes pisiform fractures can be initially overlooked because most of the time there is some other injury in the wrist, hand, or arm that distracts the patient and the physician from the pain associated with the pisiform fracture. Sometimes, CT scans along with X-rays need to be obtained so that better bony detail can be seen. This aids in the decision-making process for treatment of pisiform fractures. Often pisiform fractures can be treated with a cast, and if they continue to cause chronic pain and disability, then surgery can be performed to remove the pisiform. This causes minimal, if any, disability for the athlete, and the wrist will function fine without the pisiform.

Trapezium

Trapezium fractures are rare and often occur with the first metacarpal and/or the radius broken as well. These fractures can occur from direct injury, such as a direct blow to the trapezium, or by an avulsion mechanism from ligaments pulling on the bone. Patients with these fractures are very tender over the trapezium. On physical exam, this can sometimes be confused with the tenderness associated with scaphoid fractures because of the close proximity of the two bones. Most of the time, these types of fractures can be treated in a thumb spica cast. Usually, the cast is left on for 4 to 6 weeks, and then, removable bracing is worn for a few weeks. Sometimes, these fractures require surgery. These fractures can cause early arthritis at the base of the thumb joint, and later in life, people with these fractures may need further intervention for the arthritis that they develop.

Trapezoid Fractures

The trapezoid is protected in the wrist because it has a lot of strong ligaments that attach to it and keep it in place. Therefore, it is rarely fractured. Sometimes, a trapezoid fracture occurs when a metacarpal is fractured or when the metacarpal bone dislocates and directly impacts the trapezoid. If there is an isolated fracture of the trapezoid that is nondisplaced, it can be treated nonoperatively in a cast. Fractures that are displaced may very well need surgery.

Capitate Fractures

Capitate fractures are often difficult to diagnose and require a high index of suspicion. CT scans and MRI can be helpful in diagnosing these fractures. If these fractures are nondisplaced, they can be treated in a cast; however, displaced fractures often require surgical intervention to ensure proper healing.

Hamate Fractures

Hamate fractures cause pain on the ulnar half of the wrist. There is often swelling and tenderness over the hamate. Often several X-rays with different views of the hand have to be taken to adequately visualize a hamate fracture, and these fractures can be very subtle. Usually, if only the hamate is injured, this fracture can be casted. If the wrist feels unstable or the fracture is displaced, surgery may be needed.

There is a part of the hamate called the hook of the hamate. These fractures can easily be missed even if they are suspected. Athletes with this type of fracture usually have persistent ulnar-sided wrist pain and pain when swinging a golf club, tennis racquet, badminton racquet, or baseball bat or when playing handball. These fractures usually occur in athletes who play baseball, golf, or racquet sports because of how the bat, club, or racquet is held in the hand. These fractures can often be treated in a cast.

Jennifer Wood and Jeffrey Guy

See also Bracing; Hand and Finger Injuries; Taping

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Carpal Tunnel Syndrome

Carpal tunnel syndrome (CTS) is the most common nerve injury in the upper extremity and one of the most common nerve injuries overall. It is an injury to the median nerve at the wrist, initially causing numbness, tingling, or painful sensations in the thumb, index, middle, and half of the ring fingers. As the injury progresses, it may eventually produce weakness within the affected hand. CTS is more common in women and people who perform repetitive tasks using the wrist. Interestingly, it does not seem to correlate to handedness and is often seen in both hands. However, when present in both hands, it is generally worse in the dominant hand.

Besides our senses, our hands are the primary tools we use to manipulate and interact with our environment. While CTS is not fatal, it can lead to loss of hand function, which can greatly affect the quality of life. For athletes, difficulty or pain in using their hands can greatly impair performance as well as enjoyment of their sport.

Anatomy

The carpal tunnel is located at the wrist. Three of the four walls of the tunnel are created by the carpal (wrist) bones. The remaining wall is made of a thick band of soft tissue called the flexor retinaculum or transverse carpal ligament. Inside the tunnel, there are 10 structures: two tendons that flex each of the four fingers (the flexor digitorum superficialis and flexor digitorum profundus), one that flexes the thumb (flexor pollicis longus), and, last, the median nerve.

Causes

Compression of the nerve within the tunnel has classically been thought to cause CTS. This is partially correct, although the exact mechanism that causes CTS remains subject to debate. Compression of the wrist elevates pressure within the carpal tunnel; studies have documented nearly three to four times greater elevation in pressure with wrist flexion compared with rest. It is thought that the pressure results in ischemia (obstructed blood flow) to the nerve. The lack of blood flow to the nerve produces local injury, which results in slowed transmission over that area of the nerve. This impaired signal transduction produces the classic CTS symptoms. Of all the structures traveling through the tunnel, the median nerve is the most sensitive to changes in blood flow.

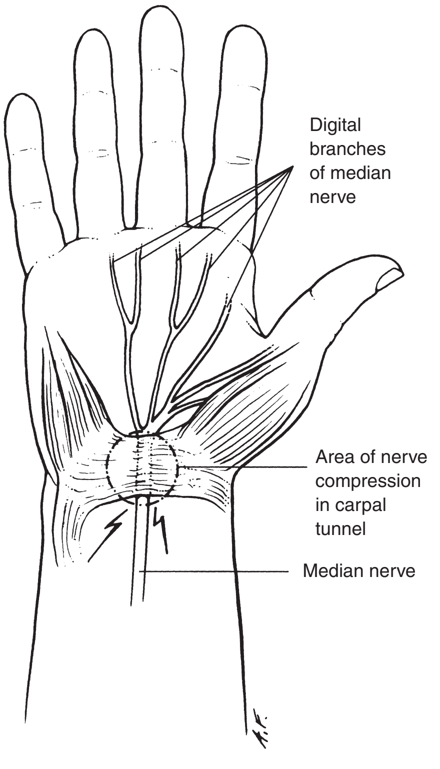

Figure 1 Carpal Tunnel Syndrome

Notes: A buildup of pressure in the carpal tunnel on the underside of the wrist can compress the median nerve that travels through this narrow channel. Carpal tunnel syndrome is the most common nerve entrapment problem in sports.

There are several risks for development of CTS, including genetic, social, and vocational. Some specific factors include diabetes, hypothyroid, wrist fractures, tumors within the tunnel, wheelchair use, and pregnancy. Environmental factors can also increase the risk of CTS. These include vibration, extreme or awkward wrist positioning (wrist flexion, wrist extension, or forceful movement at the wrist), and pressure over the carpal tunnel. There is a great deal of debate as to whether keyboard use increases the risk. Recent studies indicate that there does not appear to be any increased risk for athletes versus the general population. It is important to note that the above factors may be associated with CTS but do not and should not imply causation.

Direct trauma to the wrist can create an acute CTS, and although it is uncommon, it is important to consider in athletes participating in contact sports. More often, the repetitive movements at the wrist in sports create symptoms over time; this is most commonly seen in racquetball, tennis, golf, and bowling.

Symptoms

The median nerve is responsible for supplying innervation to several muscles within the forearm and the hand. The nerve also provides sensation to the thumb, index, middle, and half of the ring fingers. Typically, the first CTS symptoms are *paresthesias* (an unpleasant sensation described as numbness, tingling, or "falling asleep"). Most commonly, this affects the thumb, index, and middle fingers. As CTS progresses to involve the portion of the nerve controlling the muscles, there may be weakness in the hand, most often manifested as a tendency to drop objects. As the ischemia continues, the autonomic nerve fibers can also be affected. Frequently, this is reported as a change in temperature (being hot or cold all the time) or skin color or a feeling of swelling and tightness. It is speculated that when the autonomic fibers are affected, the distribution of paresthesias becomes vague, affecting the entire hand.

Pain can also be reported, most frequently at the wrist, and can extend into the forearm or palm. This pain is not reproducible with palpation to the area. As paresthesias progress, they can transition to a painful sensation (dysesthesia).

CTS symptoms are often present at night, awakening patients due to the paresthesias within the hand. Frequently, they will wake to shake their hand for relief (flick sign). Other activities, including driving, tight gripping, or holding a vibrating object can also produce symptoms.

Diagnosis

CTS is diagnosed by history and physical evaluation; electromyography (EMG) is used to confirm and grade the diagnosis. There are examination maneuvers that are suggestive but not diagnostic for CTS. Tinel and Phalen tests are two such tests that may reproduce symptoms, although the sensitivity and specificity of these is not high. In fact, studies have shown that the presence of a flick sign in the history is as specific and sensitive as Tinel or Phalen testing.

Imaging studies are of limited benefit. Magnetic resonance imaging (MRI) can be helpful in identifying tumors within the tunnel. Occasionally, MRI does show signal abnormality within the nerve, although this does not correlate to diagnosis or severity.

Electrodiagnostic testing consists of nerve conduction studies (NCS) and an electromyographic needle examination. Electrodiagnostic testing is typically referred to as EMG testing. NCS measure several characteristics of the nerve: onset, amplitude, and speed of response. Comparing these characteristics (especially the onset of response) of the median nerve with preestablished normal values, as well as with nerves (in the arm) that do not travel through the carpal tunnel, can assist in diagnosing and grading CTS. These characteristics of nerve function can be affected by age, height, temperature, and other factors that must be accounted for at the time of the study. The electromyographic testing involves a small disposable needle that is used to test muscles innervated by the median nerve after it travels through the carpal tunnel. This is helpful in grading and assessing the severity of the CTS. At the time of this writing, there is no widely accepted grading for EMG, and each individual EMG lab has its own differentiation criteria for mild, moderate, and severe CTS.

It is important to note that the above symptoms correlate to "textbook" cases of CTS, which are relatively uncommon. The range of symptoms and findings is quite large and often misleading in the diagnosis of CTS. Failure to diagnose can lead to irreversible nerve damage, and for this reason, EMG testing is strongly recommended.

Nonsurgical Treatment

A variety of oral medications, icing, and physical therapy techniques have been studied for the management of CTS; however, none have been shown to be effective. Modification of behavior to avoid activities that produce symptoms is the mainstay of initial treatment. Carpal tunnel splints that keep the wrist in a neutral position are available and can provide a great deal of relief from symptoms. For athletes, splinting at rest is tolerated; however, with activity, splinting is generally poorly tolerated. Prolonged rest (avoidance of painful behaviors) may help with the immediate symptoms but does not change the underlying pathology, and symptoms typically return with resumption of activity.

Injection of a steroid, which is an anti-inflammatory medication, within the carpal tunnel has been shown to be effective in symptom relief and can retard progression of CTS on EMG studies.

Surgical Treatment

Despite conservative treatment options, CTS can progress. If one continues to have symptoms despite conservative treatment, surgery is often recommended. Surgery is nonemergent and can be scheduled during a period of downtime (off-season), unless there are severe findings on testing. Surgical release of the transverse carpal ligament can be performed open or endoscopically (minimally invasive). Functional outcomes and relief of symptoms are nearly identical in the two procedures. Endoscopic release is associated with a slightly quicker return to full activity (including work) but also an increased risk of nerve injury. Return to full activity after surgery depends on surgeon preference and is tailored to each individual case but is generally within 2 to 4 weeks. In athletes, frequent pressure loads are placed in this high-tension area, and return to full athletic activity usually takes several weeks longer. Recurrence after surgery is extremely uncommon.

Barinder Mahal

See also Biking, Injuries in; Golf, Injuries in; Hand and Finger Injuries

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Casting and Immobilization

This entry describes casting and immobilization techniques for the injured athlete. Of the various types of casting and splinting materials used to immobilize the affected area, the two most commonly used today are plaster of paris and fiberglass. These materials come in both individual rolls (approximately 5 yards [4.57 meters] in length) and prefabricated layered rolls with padding that can be cut to length. These are available in various widths so that the affected part of the body is immobilized properly.

Splints are used immediately after the injury occurs or following surgery. Splinting is a way to immobilize the affected area and allow for swelling without compromising circulation. The splint, unlike a cast, is not circumferential and is usually placed on both the medial and the lateral side of the affected area and held in place with an elastic wrap. Many physicians prefer to use plaster of paris for splinting, owing to the greater moldability of plaster compared with fiberglass. This is true when one is trying to reduce or realign a fracture. Plaster allows a nice mold, relatively smooth against the skin, in whatever position is needed, whereas fiberglass tends to harden, with bumps and ridges that could cause irritation and other problems in the skin.

A cast is usually applied 7 to 10 days after the injury. This allows the swelling of the surrounding soft tissue to go down so that a solid cast can be applied for the remainder of the time needed for the injury to heal. If a cast is applied initially, it is a common practice to "bivalve" or split the cast with a cast saw to allow for swelling. The patient would then return for a final layer of material to make the cast solid.

In applying either a splint or a cast, the position of the affected area is extremely important. This is usually in an anatomic or neutral position, unless specified otherwise by the physician. *Note:* Sometimes the athlete is given approval by the doctor to return to sports while in the cast (usually a hand or arm cast). This could change the normal length or position of the cast. An example of this would be to apply a cast that would allow a hockey player to fit the cast or splint inside his or her glove and still be able to have a grip.

Types of Immobilization

The four basic types of casts or splints are short arm, long arm, short leg, and long leg. A short arm cast is mainly used for injuries that involve stable fractures, dislocations, or ligament or tendon injury in the distal radius, ulna, wrist, or fingers. A long arm cast is applied for the unstable injuries described above but includes the elbow or humerus. Including the elbow in the cast or splint will limit the flexion and extension of the elbow and also limit the pronation and supination of the forearm. A short leg cast is used for injuries that involve stable fractures of the distal ends of the tibia and fibula, tarsals, metatarsals, and toes. A long leg cast is applied for the unstable injuries described above but includes the knee or distal femur. Including the knee in the cast or splint will limit the flexion and extension of the knee as well as medial and lateral rotation of the lower leg.

Positioning the Patient

Positioning for a short arm or long arm cast or splint is basically the same. The patient should be sitting down, facing you with the affected arm at a 90° angle at the elbow. The wrist should be in a neutral position, with a slight extension as if shaking hands. The fingers should be spread apart to ensure that the cast is not wrapped too tightly through the hand. Certain types of fractures might require you to change the described position, but this would be specified by the physician ordering the cast or splint. Examples are certain angulations of fractures that tend to shift or unstable fractures that need to be in a position other than neutral.

Positioning for a short leg or long leg cast or splint requires having the patient lie down on his or her back with the knee slightly flexed, thus allowing the calf muscles and Achilles tendon to relax. The ankle should be at a 90° angle or neutral unless otherwise noted by the physician.

Materials Needed

The following materials are needed for casting:

- *Gloves.* The use of gloves prevents chemicals from the plaster or fiberglass from getting on your hands. It also allows you to mold the cast or splint easily.
- *Bucket.* Fill a bucket with tap water. (Warm water will cause the material to set faster.)
- *Stockinet.* This is the first layer applied to the skin. It must lie on the skin smoothly, with no wrinkles. It should be longer than the cast or splint; the ends should be folded back to make a soft cull to keep the cast or splint from rubbing against the skin.
- *Cotton rolls (Webril).* Soft cotton provides the padding between the skin and the casting or splinting material. It should be in no fewer than three to four layers. This should be applied with continuous wrapping and a 50% overlay coverage. Some extra strips should be applied where the ends of the cast or splint will be, as well as over any bony prominences.
- *Waterproof padding.* This is applied in the same manner, only no stockinet is used. It is applied in at least two layers, with extra padding at the ends and over bony prominences. This type of padding is only used with fiberglass, since plaster must not get wet. This allows the patient to shower to rinse away dirt, sweat, and dead, dried skin.
- *Plaster rolls.* These come in different widths, usually 2, 3, 4, or 6 inches (in.; 1 in. = 2.54 centimeters) wide. It is applied with the same type of coverage as the cotton roll and is usually three to four layers thick for casts. If used for splints, it is folded over on itself in the desired length and should be 10 to 15 layers thick for maximum strength.
- *Fiberglass rolls.* The same as described for plaster rolls, only 6 to 10 layers are required for splinting.
- *Bandage scissors.* These are used to cut material to conform around the web space in the thumb and also to cut off excess material and for trimming the cast or splint.
- *Tape.* This is used to cover any rough edges around the toes or thumb. It also can be used on the ends of a cast or splint.
- *Moleskin.* This is a thin adhesive felt that can be cut to size and made to adhere to the outer layer of the cast or splint, where any friction might occur.
- *Cast spreader.* This is used to split a bivalve cast. It allows for swelling.
- *Cast saw.* This is used to trim, bivalve, or remove the cast.
- *Cast knife.* This is used to trim any rough edges of the splint or cast.

Application of Cast and Splint

After positioning the patient as needed, the first layer that is applied is the stockinet. Choose the appropriate size for the affected area. Slide the stockinet over the arm or leg. If the arm is being immobilized, use your scissors to cut a slit for the thumb to come through. On a long arm cast, cut along the crease in the elbow to remove the doubled-up portion of the stockinet. On a leg cast, this cut should be made on the anterior crease of the ankle. The ends should be about 1 to 2 in. longer than where the cast or splint will stop. Remember that the stockinet will be folded over to make a cuff. This will secure the cotton padding and provide a nice cuff so that the cast or splint will not rub on the skin and cause irritation. The next layer applied is the cotton padding. This should be applied in a continuous smooth layer overlapping 50% of the coverage until the area to be casted or splinted has three to four layers of padding. Extra strips of padding are applied at the ends of the cast as well as on any bony prominences (e.g., the thumb, elbow, malleoli, or heel).

Note: If waterproof padding is used, it is applied in the same manner as the cotton padding without the stockinet.

The third and final layer of the cast or splint is either plaster or fiberglass. After donning gloves, open the roll of plaster or fiberglass. While holding onto the roll of material, dip the entire roll into the water until all the bubbles are gone. Squeeze the roll slightly (the more water that is removed from the roll, the faster the cast or splint will set). Begin to wrap the area from distal to proximal, overwrapping a 25% to 50% coverage until three to four layers are applied. This application also needs to be smooth and wrinkle-free. It is very important not to *pull* the material but to *roll* the material on the affected area. On reaching the ends of the area being covered, leave ½ in. of the padding exposed. This will be captured when the stockinet is pulled back over the material to make a cuff. One final layer of material is used to lock down the stockinet and give the cast a smooth finish.

William L. Maxwell III

See also Bracing; Emergency Medicine and Sports; Fieldside Assessment and Triage; Fractures; Taping

Further Readings

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Catastrophic Injuries

Catastrophic sports injuries in any sport are rare but tragic events. This entry reviews the nature of catastrophic sports injuries; the research findings of the National Center for Catastrophic Sports Injury Research (NCCSI), including 25 years of data collection; and the recommendations of the NCCSI and other organizations for prevention of catastrophic injuries in athletes.

The American Football Coaches Association (AFCA) initiated the First Annual Survey of Football Fatalities in 1931, and since 1965, this research has been continued at the University of North Carolina at Chapel Hill. In 1977, the National Collegiate Athletic Association (NCAA) initiated a National Survey of Catastrophic Football Injuries, and as a result, important contributions to the sport of football have been made. Most notable have been the rule changes in 1976 (which eliminated the head as a primary and initial contact area for blocking and tackling), the football helmet standard, improved medical care for the participants, and better coaching techniques.

Due to the success of these projects, research was expanded to include other sports for both men and women, and in 1982, the NCCSI was established at the University of North Carolina at Chapel Hill. Today, the NCCSI conducts research and collects data especially pertaining to the sports of baseball, ice hockey, tennis, basketball, lacrosse, swimming, cross-country running, skiing, volleyball, field hockey, soccer, water polo, football, softball, wrestling, gymnastics, and track-and-field events.

The decision to expand sports research and encompass other sports was based primarily on the following facts:

1. Research based on reliable data is essential if progress is to be made in sports safety.
2. There is a dearth of information on injuries in all sports.
3. There is a lack of injury information in women's sports.

It should also be noted that due to this research, there has been a dramatic reduction in direct fatalities at all levels of play, culminating with no fatalities in 1990. This indisputably illustrates the importance of data collection and analysis and the role that they play in injury prevention.

Definitions

The NCCSI uses the following definitions for its research.

A *catastrophic sports injury* is a sports injury that results in brain or spinal cord injury or skull or spinal fracture. It can be further subclassified as *nonfatal* or *serious*. A nonfatal injury is an injury that results in permanent severe functional (brain or spinal cord) disability, whereas a serious injury is one in which no permanent functional disability occurs, although this may be transient. An example of a serious catastrophic sports injury is a fractured cervical vertebra without permanent paralysis, whereas the same injury with quadriplegia would be classified as nonfatal.

Fatalities are classified as either *direct* (those injuries that result directly from participation in the skills of the sport) or *indirect* (those injuries that are caused by systemic failure as a result of exertion while participating in a sport activity or by a complication that is secondary to a nonfatal injury). The death of an athlete due to cardiac arrhythmias while performing a sporting activity is an example of an indirect fatality.

Research and Data Collection

The NCCSI compiles data through the assistance of coaches, trainers, athletic directors, executive officers of state and national athletic organizations, a national newspaper clipping service, and professional associates of the researchers. After notification of a possible catastrophic sports injury, the NCCSI directly contacts the athlete's coach, trainer, or athletic director. The data collected include demographics, the type and mechanism of injury, the sports equipment involved, and the immediate and subsequent medical care provided. Autopsy reports are used, if necessary. This data collection is supported by the AFCA, NCAA, and the National Federation of State High School Associations (NFHS).

Summary of Data

For the 25-year period from the fall of 1982 through the spring of 2007, there have been 1,068 direct catastrophic injuries in high school and college sports. High school sports were associated with 149 fatalities, 369 nonfatal injuries, and 346 serious injuries, for a total of 864. College sports accounted for 22 fatalities, 63 nonfatal injuries, and 119 serious injuries, for a total of 204. During this same period, there have been a total of 541 indirect injuries, and all but 11 have resulted in death. Of the indirect injuries, 439 were at the high school level and 102 at the college level. It should be noted that high school annual athletic participation (for sports with catastrophic injuries) for 2006–2007 includes approximately 7,445,742 athletes (4,605,347 males and 2,840,395 females). NCAA participation (for sports with catastrophic injuries) for 2006–2007 was 404,728 athletes (245,512 males and 159,216 females).

During the period from the fall of 1982 through the spring of 2007, there were 147,115,293 high school athletes participating in sports that are monitored by the NCCSI. Using these participation numbers would give a high school direct catastrophic injury rate of 0.59 per 100,000 participants. The indirect injury rate is 0.30 per 100,000 participants. If both direct and indirect injuries were combined, the injury rate would be 0.89 per 100,000. This means that approximately 1 high school athlete out of every 100,000 participating would receive some type of catastrophic injury. The combined fatality rate would be 0.39 per 100,000, the nonfatal rate 0.25, and the serious injury rate 0.24.

During this same period, there were approximately 8,029,283 college participants, with a total direct catastrophic injury rate of 2.54 per 100,000 participants. The indirect injury rate is 1.27 per 100,000 participants. If both indirect and direct injuries were combined, the injury rate would be 3.81. The combined fatality rate would be 1.51, the nonfatal rate 0.81, and the serious injury rate 1.49.

High School Sports

Fall

From the fall of 1982 through 2007, high school fall sports resulted in 623 direct fatalities and catastrophic injuries (Table 1), of which 603 were related to football (~97%). Indirect fatalities and catastrophic injuries (Table 2) totaled 230, of which 171 were related to football (~75%). While football had the highest incidence of catastrophic injuries among fall sports, the incidence per 100,000 athletes was still less than 1 (Tables 3 and 4).

Winter

High school winter sports led to a total of 123 direct fatalities and catastrophic injuries (Table 1), of which 58 were related to wresting (~47%) and 19 were related to basketball and ice hockey (~15% each). Indirect fatalities and catastrophic injuries (Table 2) totaled 149, of which 114 were

Table 1 Direct Catastrophic Injuries (1982–2007)

Type of Sport	*Level*	*Fatal*	*Nonfatal*	*Serious*	*Total*
Fall sports					
Cross-country	High school	0	1	0	1
	College	0	0	0	0
Football	High school	101	257	245	603
	College	9	35	89	133
Soccer	High school	7	3	6	16
	College	0	1	2	3
Field hockey	High school	0	3	0	3
	College	0	1	2	3
Winter sports					
Basketball	High school	2	5	12	19
	College	1	2	6	9
Gymnastics	High school	1	8	4	13
	College	0	5	1	6
Ice hockey	High school	2	7	10	19
	College	0	4	8	12
Swimming	High school	0	9	4	13
	College	0	1	0	1
Wrestling	High school	3	36	19	58
	College	0	1	0	1
Volleyball	High school	0	1	0	1
	College	1	0	0	1
Spring sports					
Baseball	High school	10	17	20	47
	College	3	4	5	12
Lacrosse	High school	2	4	3	9
	College	4	5	2	11
Track	High school	20	16	23	59
	College	3	4	3	10
Tennis	High school	0	0	0	0
	College	NA	NA	NA	NA
Softball	High school	1	2	0	3
	College	0	0	1	1
Equestrian	High school	NA	NA	NA	NA
	College	1	0	0	1
Other					
Cheerleading (1982–1997)[a]	High School	2	21	44	67
	College	1	9	16	26

Source: Data adapted from the *25th Annual Report on Catastrophic Injuries,* published by the National Center for Catastrophic Sports Injury Research, 2007.

Note: NA = not applicable or not available.

a. Includes Cheer Safety Foundation data.

Table 2 Indirect Catastrophic Injuries (1982–2007)

Type of Sport	*Level*	*Fatal*	*Nonfatal*	*Serious*	*Total*
Fall sports					
Cross-country	High school	24	0	0	24
	College	1	0	0	1
Football	High school	171	0	1	172
	College	41	0	0	41
Soccer	High school	31	0	0	31
	College	5	1	0	6
Water polo	High school	0	3	0	3
	College	1	0	0	1
Winter sports					
Basketball	High school	112	0	2	114
	College	28	0	1	29
Gymnastics	High school	0	0	0	0
	College	1	0	0	1
Ice hockey	High school	4	0	0	4
	College	1	1	0	2
Swimming	High school	8	0	1	9
	College	6	0	0	6
Wrestling	High school	18	0	2	20
	College	3	0	0	3
Volleyball	High school	1	1	0	2
	College	1	0	0	1
Skiing	High school	NA	NA	NA	NA
	College	1	0	0	1
Spring sports					
Baseball	High school	14	0	0	14
	College	2	0	0	2
Lacrosse	High school	7	0	0	7
	College	2	0	0	2
Track	High school	34	0	0	34
	College	1	0	0	1
Tennis	High school	3	0	0	3
	College	2	0	0	2
Softball	High school	0	0	0	0
	College	0	0	0	0
Golf	High school	0	0	1	1
	College	NA	NA	NA	NA
Rowing	High school	NA	NA	NA	NA
	College	3	0	0	3
Other					
Cheerleading (1982–1997)[a]	High School	3	NA	NA	3
	College	NA	NA	NA	NA

Source: Data adapted from the *25th Annual Report on Catastrophic Injuries*, published by the National Center for Catastrophic Sports Injury Research, 2007.

Note: NA = not applicable or not available.

a. Includes Cheer Safety Foundation data.

Table 3 Direct Catastrophic Injuries per 100,000 Participants (1982–2007)

Type of Sport	*Level*	*Fatal*		*Nonfatal*		*Serious*	
		M	F	M	F	M	F
Fall sports							
Cross-country	High school	0.00	0.00	0.02	0.00	0.00	0.00
	College	0.00	0.00	0.00	0.00	0.00	0.00
Football	High school	0.30	0.00	0.75	0.00	0.72	0.00
	College	0.49	0.00	1.89	0.00	4.80	0.00
Soccer	High school	0.10	0.00	0.03	0.02	0.09	0.00
	College	0.00	0.00	0.00	0.33	0.49	0.00
Field hockey	High school	NA	0.00	NA	0.22	NA	0.00
	College	0.00	0.00	0.00	0.72	0.00	1.43
Winter sports							
Basketball	High school	0.02	0.00	0.04	0.01	0.07	0.03
	College	0.28	0.00	0.56	0.00	1.68	0.00
Gymnastics	High school	1.04	0.00	2.08	0.97	1.04	0.48
	College	0.00	0.00	20.07	5.35	6.69	0.00
Ice hockey	High school	0.29	0.00	1.02	0.00	1.17	3.13
	College	0.00	0.00	4.18	0.00	7.32	6.49
Swimming	High school	0.00	0.00	0.24	0.14	0.14	0.04
	College	0.00	0.00	0.51	0.00	0.00	0.00
Wrestling	High school	0.05	0.00	0.60	0.00	0.32	0.00
	College	0.00	0.00	0.59	0.00	0.00	0.00
Volleyball	High school	NA	0.00	NA	0.02	NA	0.00
	College	NA	NA	NA	NA	NA	NA
Skiing	High school	NA	NA	NA	NA	NA	NA
	College	0.00	6.89	0.00	0.00	0.00	0.00
Spring sports							
Baseball	High school	0.10	0.00	0.16	0.00	0.19	0.00
	College	0.51	NA	0.68	NA	0.85	NA
Lacrosse	High school	0.26	0.00	0.52	0.00	0.26	0.19
	College	2.81	0.00	2.11	2.01	1.40	0.00
Track	High school	0.15	0.01	0.12	0.01	0.15	0.04
	College	0.34	0.00	0.34	0.15	0.34	0.00
Tennis	High school	0.00	0.00	0.00	0.00	0.00	0.00
	College	0.00	0.00	0.00	0.00	0.00	0.00
Softball	High school	NA	0.01	NA	0.03	NA	0.00
	College	NA	0.00	NA	0.00	NA	0.00
Equestrian	High school	NA	NA	NA	NA	NA	NA
	College	NA	20.59	NA	0.00	NA	0.00

Source: Data adapted from the *25th Annual Report on Catastrophic Injuries,* published by the National Center for Catastrophic Sports Injury Research, 2007.

Note: F = female; M = male; NA = not applicable or not available.

Table 4 Indirect Catastrophic Injuries per 100,000 Participants (1982–2007)

Type of Sport	*Level*	*Fatal*		*Nonfatal*		*Serious*	
		M	F	M	F	M	F
Fall sports							
Cross-country	High school	0.37	0.24	0.00	0.00	0.00	0.00
	College	0.38	0.00	0.00	0.00	0.00	0.00
Football	High school	0.50	0.00	0.00	0.00	0.01	0.00
	College	2.21	0.00	0.00	0.00	0.00	0.00
Soccer	High school	0.37	0.12	0.00	0.00	0.00	0.00
	College	0.49	1.00	0.25	0.00	0.00	0.00
Water polo (1992–2006)	High school	1.48	0.62	0.00	0.00	0.00	0.00
	College	4.06	0.00	0.00	0.00	0.00	0.00
Winter sports							
Basketball	High school	0.76	0.10	0.00	0.00	0.01	0.01
	College	6.99	0.96	0.00	0.00	0.28	0.00
Gymnastics	High school	0.00	0.00	0.00	0.00	0.00	0.00
	College	0.00	2.68	0.00	0.00	0.00	0.00
Ice hockey	High school	0.58	0.00	0.00	0.00	0.00	0.00
	College	1.05	0.00	1.05	0.00	0.00	0.00
Swimming	High school	0.05	0.25	0.00	0.00	0.00	0.04
	College	2.57	0.45	0.00	0.00	0.00	0.00
Wrestling	High school	0.30	0.00	0.00	0.00	0.03	0.00
	College	1.77	0.00	0.00	0.00	0.00	0.00
Volleyball	High school	NA	0.02	NA	0.02	NA	0.00
	College	NA	0.60	NA	0.00	NA	0.00
Skiing	High school	NA	NA	NA	NA	NA	NA
	College	6.11	0.00	0.00	0.00	0.00	0.00
Spring sports							
Baseball	High school	0.13	0.00	0.00	0.00	0.00	0.00
	College	0.34	NA	0.00	NA	0.00	NA
Lacrosse	High school	0.90	0.00	0.00	0.00	0.00	0.00
	College	1.40	0.00	0.00	0.00	0.00	0.00
Track	High school	0.22	0.06	0.00	0.00	0.00	0.00
	College	0.11	0.00	0.00	0.00	0.00	0.00
Tennis	High school	0.09	0.00	0.00	0.00	0.00	0.00
	College	0.52	0.51	0.00	0.00	0.00	0.00
Softball	High school	NA	0.00	NA	0.00	NA	0.00
	College	NA	0.00	NA	0.00	NA	0.00
Golf	High school	0.00	NA	0.00	NA	0.31	NA
	College	NA	NA	NA	NA	NA	NA
Rowing	High school	NA	NA	NA	NA	NA	NA
	College	25.65	0.00	0.00	0.00	0.00	0.00

Source: Data adapted from *25th Annual Report on Catastrophic Injuries,* published by the National Center for Catastrophic Sports Injury Research, 2007.

Note: F = female; M = male; NA = not applicable or not available.

related to basketball (~76%). Although wrestling accounted for the greatest number of direct catastrophic injuries, the incidence rate was less than 1 per 100,000 athletes (Table 3), as were those of basketball and swimming. In contrast, gymnastics and ice hockey had the highest incidence rates per 100,000 (>2 for male gymnasts with direct nonfatal injuries and >1 for male ice hockey players with direct nonfatal and serious injuries).

Spring

From 1982 through 2007, there were 118 direct fatalities and catastrophic injuries in high school spring sports (Table 1), of which 59 were related to track-and-field events (50%) and 47 were related to baseball (~40%). Of the 33 direct fatalities, 20 occurred in track-and-field events (~61%). Of the 58 indirect fatalities (Table 2), 34 were in track-and-field events (~59%) and 14 in baseball (~24%). Direct and indirect fatality and catastrophic injury incidence rates per 100,000 participants (Tables 3 and 4) were <1 for all spring sports, with the highest incidence of indirect fatalities seen in male lacrosse players (0.9 per 100,000 athletes).

College Sports

Fall

During the fall period from 1982 to 2007, there were 139 direct fatalities and catastrophic injuries in college sports (Table 1), of which 133 were related to football (~96%). Of the 49 indirect fatalities, 41 were related to football (~84%; Table 2). The incidence per 100,000 participants for football-related direct fatalities was <1 (Table 3), although the rates were 1.89 and 4.8 for direct nonfatal and direct serious injuries, respectively. The indirect fatality and catastrophic injury incidence per 100,000 athletes (Table 4) was <1 for all sports except for female soccer players (1 fatality per 100,000 athletes) and male football players (2.21 fatalities per 100,000 athletes).

Winter

College winter sports caused 30 direct fatalities and catastrophic injuries (Table 1), 12 of which occurred in ice hockey (40%) and 9 in basketball (30%). There were 41 indirect fatalities (Table 2), of which 28 were related to basketball (~68%). Incidence rates per 100,000 athletes (Table 3) for direct fatalities and catastrophic injuries ranged from 0 (basketball-related direct fatalities in females) to 20.07 (gymnastics-related nonfatal direct catastrophic injuries in males). Indirect fatality rates per 100,000 athletes ranged from 0 in gymnastics (male) to 6.99 in male basketball players and 6.99 in male skiers (Table 4).

Spring

Spring sports among college athletes had 35 direct and catastrophic injuries (Table 1). Of these, 12 were reported in baseball (~34%), 11 in lacrosse (~31%), and 10 in track-and-field events (~28%). The 10 indirect fatalities (Table 2) included 3 in rowing and 2 each in baseball, lacrosse, and tennis. The rate of direct and indirect fatalities and catastrophic injuries was <1 per 100,000 athletes in all college spring sports except lacrosse (Tables 3 and 4).

Injury Prevention in Sports

The data and trends obtained from 1982 through 2007 provide the background for considering sport-specific and general recommendations to help reduce fatality and catastrophic injury rates. Additionally, fatalities and catastrophic injuries in female athletes, especially cheerleaders, deserve particular attention.

Sport-Specific Prevention Recommendations

Football

While the numbers of football-related fatalities and catastrophic injuries have decreased dramatically since 1976, there is still room for improvement, and therefore, further steps are warranted. These steps should emphasize the preventive measures that have already been successful:

1. Continued enforcement of the ban on initial contact with the head in blocking and tackling, along with coaching in the proper skills of blocking and tackling
2. Ongoing research on helmet safety, continuing the effort that led to the establishment of a helmet standard by the National Operating Committee on Standards for Athletic Equipment

3. Improved medical care for injured athletes, including the hiring of athletic trainers and the writing of emergency plans for catastrophic injuries at all high schools and colleges

Specific recommendations from the NCCSI were outlined in the 2007 Annual Survey of Football Injury Research (1931–2007). These recommendations include the following:

1. Mandatory medical examinations and medical history should be taken before allowing an athlete to participate in football. The NCAA recommends a thorough medical examination when the athlete first enters the college athletic program and an annual health history update with use of referral exams when warranted. If the physician or coach has any questions about the athlete's readiness to participate, the athlete should not be allowed to play. High school coaches should follow the recommendations set by their State High School Athletic Associations.
2. All personnel concerned with training football athletes should emphasize proper, gradual, and complete physical conditioning. Particular emphasis should be placed on neck-strengthening exercises.
3. A physician should be present at all games and practice sessions. If it is impossible for a physician to be present at all practice sessions, emergency measures must be provided. Written emergency procedures are recommended for both coaches and medical staff.
4. All personnel associated with football participation should be cognizant of the problems and safety measures related to physical activity in hot weather.
5. Each institution should strive to have a team trainer who is a regular member of the faculty and is adequately prepared and qualified.
6. A cooperative liaison should be maintained by all groups interested in the field of athletic medicine (coaches, trainers, physicians, manufacturers, administrators, etc.).
7. There should be strict enforcement of game rules, and administrative regulations should be enforced to protect the health of the athlete. Coaches and school officials must support the game officials in their conduct of athletic contests.
8. There should be a renewed emphasis on employing well-trained athletic personnel, providing excellent facilities, and securing the safest and best equipment possible.
9. There should be continued research concerning the safety factor in football (rules, facilities, equipment, etc.).
10. Coaches should continue to teach and emphasize the proper fundamentals of blocking and tackling to help reduce head and neck fatalities.
11. Strict enforcement of the rules of the game by both coaches and officials will help reduce serious injuries. Be aware of the 2005 rule change to the 1976 definition of spearing.
12. When a player experiences or shows signs of head trauma (loss of consciousness, visual disturbances, headache, inability to walk correctly, obvious disorientation, memory loss), he or she should receive immediate medical attention and should not be allowed to return to practice or the game without permission from the proper medical authorities.
13. The number of indirect heart-related deaths has increased over the years, and it is recommended that schools have automated external defibrillators (AEDs) available for emergency situations.

Other recommendations from the NCCSI were outlined in the 2007 Annual Survey of Catastrophic Football Injuries (1977–2007). These recommendations include the following:

1. Brain and spinal injuries in football have been dramatically reduced since the rules were changed in 1976 to prohibit butt blocking and face tackling and other techniques in which the helmet and face mask purposely received the brunt of the initial impact. There are still a small number of football players who became paralyzed due to cervical cord injury. Because head contact largely caused these injuries, it is important to remember to keep the head and the face out of the way during blocking and tackling. Coaches should drill the players in the proper execution of the fundamentals of football—particularly blocking and tackling. Shoulder block and tackle with the head up. Keep the head out of range of the football.
2. Preseason physical exams should be taken for all participants. Identify during the physical exam

those athletes with a history of previous brain or spinal injuries. If the physician has any questions about the athlete's readiness to participate, the athlete should not be allowed to play.

3. Athletes must be given proper conditioning exercises that will strengthen their necks to enable them to hold their heads firmly erect while making contact during a tackle or block. Strengthening of the neck muscles may also protect the neck from injury.
4. Coaches and officials should discourage the players from using their heads as battering rams when blocking, tackling, and ball carrying. The rules prohibiting spearing should be enforced in practice and in games. The players should be taught to respect the helmet as a protective device and that the helmet should not be used as a weapon. Ball carriers should also be taught not to lower their heads when making contact with the tackler.
5. Football officials can play a major role in reducing catastrophic football injuries. The use of the helmet/face mask to make initial contact while blocking and tackling is illegal and should be called for a penalty. If more of these penalties are called, there is no doubt that both players and coaches will get the message and discontinue this type of play. A reduction in helmet/face mask contact will result in a reduction of catastrophic football injuries.
6. All coaches, physicians, and trainers should take special care to see that the players' equipment is properly fitted, particularly the helmet.
7. It is important, whenever possible, for a physician to be on the field of play during games and practice. When this is not possible, arrangements must be made in advance to obtain a physician's immediate services when emergencies arise. Each institution should have a team trainer who is a regular member of the institution's staff and who is qualified in the emergency care of injuries, both in treating and in preventing them.
8. Coaches must be prepared for a possible catastrophic head or neck injury. The entire staff must know what to do. Being prepared and knowing what to do may be the difference that prevents permanent disability. Have a written emergency plan and give copies to all personnel.
9. When a player experiences or shows signs of head trauma (loss of consciousness, visual disturbances, headache, inability to walk correctly, obvious disorientation, memory loss), he or she should receive immediate medical attention and should not be allowed to return to practice or games without permission from the proper medical authorities.
10. Coaches should encourage players to let them know if they have any of the aforementioned symptoms (especially those that are not apparent to others, e.g., headaches) and instruct them on why it is important to do so.
11. Both past and present data show that the football helmet does not cause cervical spine injuries but that poorly executed tackling and blocking are the major problem.

Although catastrophic injuries in football may never be totally eliminated, continued research has resulted in rule changes, equipment standards, improved medical care, and changes in the fundamental techniques of the game.

Soccer

It should be noted that from 1979 to 2008, according to the U.S. Consumer Product Safety Commission (CPSC), there have been 34 deaths and 51 injuries from movable soccer goals. Safety measures include anchoring the goals, warning players to avoid climbing on them, and using proper moving, maintenance, and storage techniques. Guidelines for movable soccer goal safety are available from the CPSC at http://www.cpsc.gov/cpscpub/pubs/5118.html.

Wrestling

High school and college wrestling resulted in 82 direct fatalities and catastrophic injuries between 1982 and 2007. Since only four of these occurred at the college level, continued research should focus on high school wrestling. High school coaches should be well versed in the skills of the sport as well as proper conditioning techniques and safety measures; physical education teachers also need training in wrestling skills. Physical education classes should include full-speed wrestling only if sufficient time is available to teach conditioning and skills. Another important issue is improper weight reduction, which can lead to serious injury or death. During the 1997–1998 academic year, there were three college wrestlers who died of heat stroke complications while trying to make weight for a match. These were the first wrestling deaths associated with weight reduction; however, there is no information on the number of wrestlers who had medical problems associated with weight loss but recovered. Making weight has always been a part of the wrestling culture, but it is dangerous and life threatening. A significant rule change approved by the NFHS Board of Directors in April 2005 states that in 2006–2007 stronger guidelines discouraging rapid weight loss will take effect. The revised rule states that specific gravity should not exceed 1.025, body fat assessment should be no lower than 7% in males and 12% in females, and a monitored, weekly weight loss plan should not exceed 1.5% per week.

Gymnastics

Since male and female gymnasts have high injury rates in high school (13 out of 20) and college, injury mechanisms and preventive measures should be investigated further at both levels. Both levels have seen a dramatic reduction in participation, and this trend may continue, particularly in private clubs.

Ice Hockey

While the absolute number of ice hockey injuries in high school and college is low (31 direct and 6 indirect fatalities and catastrophic injuries), the fatality and catastrophic injury rates per 100,000 participants are higher than in many other sports (1.05 indirect fatalities per 100,000 male college ice hockey players and 4.18 direct nonfatal and 7.32 direct serious catastrophic injuries per 100,000 male college ice hockey players). Catastrophic injuries in ice hockey usually occur when an athlete is struck from behind or falls and hits the crown of his or her head on the boards, resulting in a fractured cervical vertebrae and paralysis. Tator and colleagues, who did an extensive survey on catastrophic injuries in Canadian ice hockey that was published in the *Canadian Journal of Surgery* in 1999, recommended the following:

1. Enforce current rules, and consider new rules against pushing or checking from behind.
2. Develop conditioning programs to help players strengthen their neck muscles.
3. Instruct players about the risk of neck injury.
4. Continue epidemiologic research.

Swimming

All catastrophic injuries in swimming have occurred when swimmers struck their head on the pool bottom while doing a racing dive in the shallow end. After the swimming community was made aware of this fact, the rules were changed. Rules to ensure that there is adequate depth when swimmers enter the water were created by the NFHS Swimming and Diving Rules Committee in the early 1990s. The NFHS Swimming and Diving Rules Book (Rule 2–7-2) states that in pools with water depth less than 3.5 feet (ft; 1 ft = 30.48 centimeters [cm]) at the starting end, swimmers will have to start the race in the water. The rules read that in 4 ft or more of water, swimmers may use a starting platform up to a maximum of 30 inches (in.; 1 in. = 2.54 cm) above the water and the pool depth shall be measured for a distance of 16 ft 5 in. from the end wall. Between 3.5 and 4 ft, swimmers start from the pool deck or in the water. The NCAA and USA Swimming have or are in the process of changing the standard for the use of starting blocks to a minimum depth of 5 ft. In April 1995, the NFHS revised Rule 2–7-2, which now states that starting platforms shall be securely attached to the deck or wall in pools with water depth of 4 ft or more in the starting end. If they are not, they shall not be used, and deck or in-water starts will be required. These new rules point out the importance of constant data collection and analysis. Rules and equipment changes for safety reasons must be based on reliable injury data. The NCCSI has not received any information concerning direct catastrophic swimming injuries in high school or college during the 2006–2007 season. NFHS guidelines for swimming are available at http://www.nfhs.org.

Baseball

From 1982 to 2007, high school baseball has caused 47 direct fatalities and catastrophic injuries. Most of these injuries occurred during a head-first slide or when a player was struck with a thrown or batted ball. If the head-first slide is to be allowed in high school, coaches must teach players the safest ways to execute this maneuver. Proper protection should be provided for the pitcher during batting practice, and he or she should always wear a helmet. This should also be true for the batting practice coach. During the 2007 baseball season, three high school pitchers were struck in the head with batted balls. One pitcher recovered, one injury was nonfatal at the time of writing, and one pitcher died. One injury took place in a scrimmage game, one in batting practice, and one in a batting cage. A new rule in fast-pitch softball will require players to wear batting helmets equipped with face masks/guards that meet the standards set by the National Operating Committee for Standards in Athletic Equipment (NOCSAE). The rule came into effect on January 1, 2006.

Track-and-Field Events

From 1982 through 2007, high school track-and-field events resulted in 20 direct fatalities and 39 catastrophic injuries. The pole vault was associated with the majority of the fatal track injuries. There have been 18 high school and college fatal pole-vaulting injuries from 1983 to 2006. In addition to the fatalities, there were also 11 permanent disabilities (8 in high school and 3 in college) and 7 serious injuries (5 high school, 1 college, and 1 middle school). All 36 of these accidents involved the vaulter bouncing out of or landing out of the pit area. The three pole-vaulting deaths in 1983 were a major concern, and immediate measures were taken by the NFHS. Beginning with the 1987 season, all individual units in the pole vault–landing area had to include a common cover or pad extending over all sections of the pit. Additional recommendations have been added since. Another contentious issue is that of pole vaulters being required to wear helmets. While many high school associations have or are considering mandatory use of the helmet, the NCAA has reserved it as a personal option to be decided by the athlete.

There have also been 23 accidents in high school track involving participants being struck by a thrown discus, shot put, or javelin. Good risk management and safety precautions must be stressed for these events in both practice and competitive meets to prevent this type of accident. The NFHS put a new rule in place for the 1993 track season that fenced off the back and sides of the discus circle to help eliminate this type of accident.

Lacrosse

Only one direct death (and no catastrophic injuries) has occurred in high school lacrosse. The fatality occurred when a player struck an opponent with the top of his helmet. This technique is prohibited by the lacrosse rules and should be strictly enforced. Lacrosse has been a fairly safe sport when considering the fact that high school lacrosse has been involved in only nine direct catastrophic injuries in 25 years. A possible new area of concern is the recent lacrosse deaths associated with players being struck in the chest with the ball, causing death, a phenomenon known as *commotio cordis*.

Commotio cordis is the uneventful consequence of a concussion of the heart from nonpenetrating blunt trauma to the anterior chest. On occasion, it can lead to fatal cardiac arrest, due to either myocardial trauma or the mechanoelectrical triggering of a ventricular tachyarrhythmia. Commotio cordis was first described in 1932 in large rabbits, but later on, it came to the attention of clinicians who encountered children dying suddenly from a chest blow while engaging in sports activities. Although reported at a wide range of ages (3 months to 50 years), commotio cordis typically afflicts children and adolescents (mean age 13 years) because the young have narrow, pliable chest walls that facilitate transmission of energy from the chest impact to the myocardium. Most events are caused by blows from "projectiles," such as baseballs or lacrosse balls, with a substantial proportion occurring despite the use of a chest protector. Activation of the sympathetic nervous system has been proposed as a potential mechanism of sudden death in commotio cordis. However, in an experimental model, autonomic blockade has no effect on the frequency of sudden cardiac death (SCD), polymorphic ventricular tachycardia, or ST segment elevation. It has been further confirmed that vagotonic and sympathetic surges do not provide a major pathogenetic contribution to the syndrome of SCD due to chest blows. Therefore, commotio cordis can cause SCD by acute initiation of ventricular fibrillation. Particularly, baseball impacts induce ventricular fibrillation when directed at the center of the left ventricle during the vulnerable part of repolarization just prior to the T-wave peak.

There have been seven cases of commotio cordis (two high school, one high school club, three college, and one summer camp) since 1996. Currently, there is research being funded by the NOCSAE for the study of chest protectors to help reduce commotio cordis–related fatalities. Following injury to a female lacrosse player in 2003, protective eyewear was required for all high school participants in the states that follow NFHS rules and for all competitors at the NCAA championships. In 2005, the requirement was extended to the entire season for all NCAA teams. Early reports indicate a major reduction in eye injuries for female lacrosse players. Injury rates are slightly higher in college lacrosse, but the participation figures are so low that even one injury will increase the incidence rate dramatically. It is important to point out that there have been nine male and two female college lacrosse players with catastrophic injuries during the past 25 years. There were no direct or indirect injuries to college lacrosse players in the 2006–2007 academic year.

Cheerleading

The NCCSI has been collecting cheerleading catastrophic injury data during the past 25 years (see Tables 1 and 2). There were two college and one high school cheerleading catastrophic injuries during 2006–2007. Cheerleading has changed dramatically and now has two distinctive purposes: (1) of a service-oriented leader of cheer on the sideline and (2) as a highly skilled competing athlete.

A number of high schools and colleges across the United States have limited the types of stunts that can be attempted by their cheerleaders. Rules and safety guidelines now apply to both practice and competition. As stated in the *25th Annual Report on Catastrophic Injuries,* published by the NCCSI in 2007, high school and college cheerleaders account for more than half of the catastrophic injuries to female athletes. Inexperienced and untrained coaches should not attempt to teach stunts with a higher level of difficulty than their team is capable of achieving or they have the knowledge and ability to teach. The following is a list of sample guidelines that may help prevent cheerleading injuries:

1. Cheerleaders should have a medical examination done before they are allowed to participate. A complete medical history should be included.
2. Cheerleaders should be trained by a qualified coach with training in gymnastics and partner stunting. This person should also be trained in the proper methods for spotting and other safety factors.
3. Cheerleaders should be exposed to proper conditioning programs and trained in proper spotting techniques.
4. Cheerleaders should receive proper training before attempting gymnastics and partner-type stunts and should not attempt stunts they are not capable of completing. A qualification system demonstrating mastery of stunts is recommended.
5. Coaches should supervise all practice sessions in a safe facility.
6. Mini trampolines and flips or falls off of pyramids and shoulders should be prohibited.
7. Too high pyramids should not be performed without mats and other safety precautions.
8. If it is not possible to have a physician or certified athletic trainer at games and practice sessions, emergency procedures must be provided. The emergency procedure should be in writing and available to all staff and athletes.
9. There should be continued research concerning safety in cheerleading.
10. When a cheerleader experiences or shows signs of head trauma (loss of consciousness, visual disturbances, headache, inability to walk correctly, obvious disorientation, memory loss), she or he should receive immediate medical attention and should not be allowed to practice or cheer without permission from the proper medical authorities.
11. Cheerleading coaches should have some type of safety certification. The American Association of Cheerleading Coaches and Advisors offers this certification.

It is the opinion of the NCCSI that following cheerleading rules and safety manual guidelines that are written by cheerleading experts is an

Catastrophic Injury Prevention Recommendations

- All athletes should be required to undergo a preparticipation physical examination.
- All schools should provide teams with a qualified trainer; accessible, written emergency procedures; and excellent and safe facilities and equipment.
- Coaches should be well trained in physical conditioning, the skills of their sport, and the risks of injury and be able to teach these effectively to young athletes.
- Game officials must enforce the rules strictly, and coaches should support officials' efforts to conduct safe competitions.
- In addition, continued sports-related research will provide the injury data and analysis necessary to formulate changes in rules, facilities, and equipment to help prevent tragedies.

excellent way to help prevent injuries during cheerleading. The new restrictions can be found on the American Association of Cheerleading Coaches and Administrators (AACCA) website, http://www.aacca.org.

General Prevention Recommendations

Besides the above-mentioned sport-specific considerations, the data collected by the NCCSI also suggest the above general safety recommendations.

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See also Emergency Medicine and Sports; Fieldside Assessment and Triage; Head Injuries; Neck and Upper Back Injuries; Sudden Cardiac Death

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Cervical and Thoracic Disk Disease

The spine, commonly known as the "backbone," extends from the skull to the pelvis and forms the vertical axis of the skeleton. The cervical spine is the portion of the spine that is located in the neck. The thoracic spine is the portion of the spine that is located in the middle back, from the base of the neck to the lowest rib. Cervical disk disease is common, accounting for more than one-third of all spinal disk disease. Thoracic disk disease is less common than cervical disk disease, probably because the ribs limit the amount of movement between these vertebrae, thus decreasing the risk for injury. It accounts for less than 1% of all disk disease.

Anatomy and Pathology

The spine is actually a series of 24 small bones called vertebrae and two large bones called the sacrum and coccyx. The coccyx is commonly referred to as the tailbone. Every vertebra has an anterior vertebral body and a posterior bony arch. The spinal cord extends from the brainstem to the coccyx and passes through this arch with nerves exiting at every level. The cervical spine refers to the 1st through 7th vertebrae. It starts at the base of the skull and ends at the shoulders. The term *thoracic spine* refers to the 12 vertebrae below the cervical vertebrae. It starts at the shoulders and ends at the lower back. The last thoracic vertebra is adjacent to the lowest rib. In between each vertebral body is a gelatin-like cushion, or *disk*, known as the *intervertebral disk*. Each vertebra articulates with the adjacent vertebrae in a tripod fashion, with the disk in front and the two facet joints on the posterior bony arch. The disk comprises an outer annulus and an inner gelatinous component called the *nucleus pulposus* (nucleus). The outer annulus consists of concentric layers of ligamentous sheaths surrounding the nucleus. The majority of load-bearing forces go through the disk, which is there for stability and fluidity of motion. The inner nucleus has some substances that are inflammatory and cause pain when leaked beyond the annulus. The nerve roots exit the spine at each level to innervate specific muscle groups in the extremities and trunk. The cervical nerve roots innervate the muscles of the upper extremities, and the thoracic nerves innervate the chest and abdominal muscles. These nerve roots also serve to give sensation to specific areas on the trunk and extremities. When these nerves are irritated, they tend to send pain in the direction of this sensory distribution and may be associated with specific muscle weakness in this distribution. These radiating symptoms are called radicular symptoms.

When a disk has an acute herniation, the inner nucleus breaks through the ligamentous annulus and may directly compress a nerve root. The herniated disk may cause radicular symptoms due to the mechanical bulk of the disk on the nerve root or the chemical inflammation around the nerve root.

In contrast, disk degeneration is a slow process that involves gradual dehydration of the normally hydrated nucleus as well as breakdown of the surrounding ligamentous annulus. This will appear on a magnetic resonance imaging (MRI) scan as darkening and a diminished disk height. This is believed to be a normal process of aging and is often not associated with any symptoms. Several bony changes may also occur concomitantly. The vertebral bodies above and below the disk may exhibit some swelling, called bony edema, that is seen on an MRI scan. This finding may be associated with pain. Another bony finding with disk degeneration is called the *disk-osteophyte complex*. In this situation, a very slow and gradual disk herniation causes a coexisting bone spur that may press on the nerve root along with the disk material.

Clinical Presentation

Disk degeneration is a common finding, with 25% of those under 30 and 75% of those above 50 showing these changes without any correlation of pain. However, symptomatic disk disease will present differently based on the nature of the disease and its location. The symptoms may be more central (axial pain) or peripheral (radicular pain). Axial pain refers to pain in the posterior head, neck, and shoulders. Radicular pain reflects symptoms in the arms and upper back. It may be associated with numbness, tingling, or a feeling of "pins and needles" in the arms. This phenomenon is known as *paresthesias*. Most readers will be familiar with this as the sensation they experience after sitting with their legs crossed for an extended period or after banging their funny bone. Weakness of the arms may also occur. This indicates that the nerves that supply power to the arm have been affected. Thoracic disk disease will usually manifest as pain in the upper and mid back with some possible radiation to the chest and abdomen. In severe cases, the nerves to the legs may be affected as well as those that control bowel and bladder function.

Clinical Evaluation

History

Cervical disk herniation will usually result in neck pain. If the herniation occurs at or below the fourth cervical vertebra, it may be associated with shoulder or arm pain. In addition, herniation at or below this level may cause paresthesias—numbness, tingling, or a feeling of "pins and needles"—in the arms. Weakness of the shoulder or arm muscles may also occur.

Patients with thoracic disk herniation will most commonly complain of pain. Less commonly, they may have paresthesias, weakness of the core musculature, or a frequent urge to urinate.

Physical Examination

The physical examination begins with inspection: looking for swelling, bruising, abrasion, lacerations, or other evidence of injury. Feeling or palpating the back of the neck and thoracic portion of the spine may reveal tenderness. As disk herniation is often associated with nerve involvement, testing of the sensation, reflexes, and strength of the neck, shoulder, arm, and back is used to help determine whether a nerve is involved. Often, the particular location of the involved nerve can be determined. In patients who show no positive findings in these components of the physical examination, the clinician places the neck or back in various positions and ask the patient if these positions re-create the symptoms. These are called provocative maneuvers and can help determine the underlying cause of the symptoms.

Diagnostic Tests

The information obtained from the history and physical examination is used to decide whether diagnostic tests are necessary. Sometimes, pictures of the spine, the intervertebral disks, the surrounding muscles, and other tissues are useful. X-rays, computed tomography (CT) scans, and MRI scans are all types of images that may be helpful. Electromyograms and nerve conduction studies may sometimes be useful in assessing whether any nerve damage has occurred.

Treatment

Many cervical and thoracic spine injuries can be prevented, in particular by strengthening and increasing the flexibility of the muscles that support the neck and thoracic spine.

However, when symptoms occur, they are initially treated with relative rest by removing the athlete from play and other activities that stress the affected portion of the spine. In addition, immobilization in a brace or collar may be employed for very short periods. Anti-inflammatory medications, the application of ice or heat, and massage may be added to the therapy. Sometimes, traction may be applied to the spine by pulling gently on the head or hips of the patient to take some of the pressure off of the affected disks.

Once the patient's acute pain has resolved or significantly improved, physical therapy focused on strengthening and stretching the muscles that support the neck and thoracic spine will be recommended. If patients have symptoms that persist or recur frequently, injections of corticosteroids into the area of disk disease may be helpful. At times, if none of the above treatments are effective, surgical procedures may be considered.

Return to Sports

Generally accepted guidelines or standards for returning the athlete to sports after management of cervical or thoracic disk disease are incomplete. However, the athlete should be completely symptom-free and should demonstrate a full and painless range of motion and full strength, along with a normal neurologic examination. The physician will also need to determine that there is no severe narrowing (stenosis) around the spinal cord. If all of these are felt to be satisfactory, most athletes may return to play.

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See also Back Injuries, Surgery for; Cervical and Thoracic Fractures and Traumatic Instability; Emergency Medicine and Sports; Fieldside Assessment and Triage; Lower Back Injuries and Low Back Pain; Musculoskeletal Tests, Spine; Slipped Disk; Spinal Cord Injury

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Cervical and Thoracic Fractures and Traumatic Instability

While the assessment of each and every athletic injury requires thorough evaluation, the evaluation of possible spinal cord injuries should be especially meticulous and careful. Because the consequences of spinal cord injury can be devastating, there should be little margin for error in its treatment, beginning the instant the injury is sustained. A wide range of such injuries can occur, from sprains to fracture-dislocations with resultant paralysis. This entry will focus on cervical fractures, thoracic fractures, and traumatic instability of the spine.

Initial Evaluation

Any athlete who is suspected of having a spinal cord injury on the field should not be moved until he or she has been adequately immobilized. Symptoms that could indicate spinal cord injury include paresthesias, or numbness, tingling, or "pins and needles"; weakness in the extremities; radiating pain from the site of injury to other body parts; midline neck or back pain; inability to move body parts; or decreased level of consciousness. Athletes who are unconscious should be treated as if they have sustained a spinal cord injury. Athletes should be evaluated for neurological and respiratory compromise. Emergency medical services should be notified, and the patient should be transported to a hospital for further evaluation.

If a spinal cord injury is suspected, adequate immobilization consists of cervical spine (C spine) in-line immobilization with placement of a rigid cervical collar. A logroll maneuver should be used to place the patient on a long spine board. If the injury is sustained during football play, the helmet should *not* be removed if the shoulder pads are on because this hyperextends—stretches beyond the normal range of motion—the neck, and is unacceptable for immobilization purposes. The face mask can be removed using a proper face mask removal tool. Shoulder pads should not be removed on site.

Cervical Spine Fractures, Dislocations, and Instability

C-spine injuries can involve the vertebrae, intervertebral disks, spinal cord, nerves, or ligamentous supporting structures. The C spine consists of seven vertebrae, numbered C1 through C7. C1 is often referred to as the atlas, and C2 is referred to as the axis. There are a wide range of injuries that can occur, from sprains to fracture-dislocations with resultant paralysis. Dislocations and fractures can be categorized as stable or unstable.

Appropriate work-up of possible C-spine injuries includes X-rays and, possibly, computed tomography (CT) and magnetic resonance imaging (MRI) scans. CT scans are best used to provide fine bony detail, whereas MRI scans are superior for assessment of soft tissue injury.

Upper C-spine injuries occur at the junction of the occiput and C spine or the C1 and C2 vertebrae. Two serious types of instability that can occur in this area include occipitocervical injuries and atlantoaxial instability.

Occipitocervical injuries rarely occur in sports and most often are the result of high-speed motor vehicle accidents. These are devastating injuries, and most individuals do not survive. Rigid immobilization until surgery can be performed is mandatory.

Atlantoaxial instability is characterized by excessive movement between the atlas, C1, and the axis, C2. The alar and transverse ligaments are responsible for atlantoaxial stability, and flexion injuries can rupture these structures, causing resultant impingement of the spinal cord. Athletes with this injury complain of neck pain; often torticollis with limited neck motion and can have neurological symptoms. Diagnosis can be made with X-rays of the C spine, and often a CT scan is needed as well.

Common fractures in the upper C spine consist of C1 fractures, odontoid fractures, and hangman's fractures. C1 ring fractures often can be treated with rigid immobilization; the type of rigid immobilization varies from cervical collars to halo vest immobilization depending on the type of fracture that has occurred. Jefferson fractures are a subtype of C1 fractures, which are typified by a four-part break in C1 involving both the anterior and the posterior arches. These fractures can be unstable, and often more aggressive treatment is required, including operative intervention.

Middle and Lower C-Spine Fractures and Dislocations

Fractures and dislocations to the C3-C7 vertebrae can cause a variety of symptoms, including neck pain, transient paresthesias, paralysis, respiratory compromise, and neurogenic shock. Generally, these injuries can consist of facet fracture-dislocations, vertebral fractures, and spinous process fractures. Advanced imaging, such as CT and MRI scans, are often necessary in identifying these injuries.

Facet fracture-dislocations often need reduction by a trained orthopedist or neurosurgeon. Reductions are necessary, especially in patients with incomplete or complete spinal cord deficits, but they have the potential to cause neurological deficit. Therefore, reductions should be performed on awake patients so that feedback and a physical exam can be performed if necessary. Bilateral facet dislocations always require surgical stabilization.

There are a variety of fractures associated with axial load injuries, including burst, compression, and teardrop fractures. These injuries affect the anterior column of the vertebral column. The treatment required for an axial load injury is determined by neurological status and stability. If there is a spinal cord injury, often surgical intervention is required.

Spinous process fractures can be part of an unstable cervical spine fracture pattern or can be a relatively benign injury. These types of fractures usually occur when the neck is hyperextended or hyperflexed. Flexion-extension X-rays may be needed to identify unstable fracture patterns.

Thoracic Trauma

The thoracic spine is composed of the 12 thoracic vertebrae and is the middle segment of the vertebral column, located between the cervical and the lumbar vertebrae. All the thoracic vertebrae except for the 11th and 12th articulate with the ribs.

There are multiple types of injury patterns that can occur in the thoracic spine. The *three-column* concept is often referred to when describing spinal fractures. The spinal column can be divided into three sections: the anterior column, the middle column, and the posterior column. The anterior column is composed of the anterior longitudinal ligament and the anterior half of the vertebral body, disk, and annulus. The middle column is composed of the posterior half of the vertebral body, disk, annulus, and posterior longitudinal ligament. The posterior column is composed of the facet joints, the ligamentum flavum, and the posterior elements. In general, fractures are considered stable only if the anterior column is involved. The greater the number of columns that are involved, the more unstable is the injury.

The specific types of injuries to the thoracic spine include compression fractures, stable burst fractures, unstable burst fractures, flexion-distraction (chance) injuries, and fracture-dislocations. *Compression fractures* are vertebral body fractures that affect only the anterior column of the spine. They are often stable and most of the time

Type of Fracture	*Columns Involved*	*Stability*
Compression	Anterior	Often stable
Burst	Anterior, posterior	Sometimes stable
Chance	Anterior, middle, posterior	Likely unstable

can be treated with brace immobilization. *Stable burst fractures* involve the posterior cortex, facet joints, and lamina but do not have any displaced fractures. Often, these can be treated with custom-fit orthoses. *Unstable burst fractures* affect the middle and anterior columns, have displaced fractures of the facet joints and lamina, and often require surgical stabilization. *Chance fractures* are flexion-distraction injuries that affect the anterior, middle, and posterior columns. Casting, bracing, or surgery is necessary for a chance fracture. *Fracture-dislocations* of the vertebrae almost always require surgical stabilization.

Thoracic fractures that do not require surgical stabilization are often treated in orthoses. The main function of an orthosis is to provide stability by limiting trunk motion and motion among the vertebrae.

Nonoperative treatment of single-column injuries often involves the use of an extension orthosis to limit flexion. Isolated posterior element fractures, such as spinous process fractures, are typically stable, and thus, they are treated symptomatically and conservatively with mobilization and pain control.

Injuries involving two columns require more rigid immobilization than single-column injuries. Thoracolumbosacral orthoses provide good immobilization if the injury is in the lower thoracic spine, that is, T7 and distal. For more proximal thoracic injuries, the brace is extended to a cervical thoracolumbosacral orthosis or a halo with vest.

Conclusion

The overall prognosis for spinal injuries depends on the level of neurologic compromise. Fracture patterns vary from stable with no neurologic injury or sequelae to devastating injuries that are fatal. The initial treatment is crucial, and if a spinal cord injury is suspected, spinal immobilization is prudent. Diagnosis of vertebral fractures and spinal cord injuries is made by careful physical exam, including a detailed neurologic exam, and various imaging modalities that may include but not be limited to X-ray, to identify basic fractures; MRI, to look for soft tissue and spinal cord injury; and CT scan, to detect occult fractures. Treatment options range from symptomatic treatment of pain to external bracing to surgical stabilization. Overall, outcome is related to the specific fracture pattern and the spinal cord injury that is sustained.

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See also Back Injuries, Surgery for; Cervical and Thoracic Spine Injuries; Emergency Medicine and Sports; Fieldside Assessment and Triage; Football, Injuries in; Musculoskeletal Tests, Spine; Neck and Upper Back Injuries; Slipped Disk; Spinal Cord Injury

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Cervical and Thoracic Spine Injuries

Cervical and thoracic spine injuries are not uncommon in sports. Cervical spine injuries are especially common in collision sports such as football and ice hockey, occurring in 10% to 15% of U.S. football players. Fortunately, most of these injuries are self-limited, and full recovery is usually achieved. Devastating injuries, however, do occur. Between 1982 and 1994, there were more than 300 catastrophic injuries involving the cervical spine. Approximately 7% of all cases of spinal cord injury are related to athletics.

Anatomy

The spinal column, or "backbone," is actually a series of 24 small bones called vertebrae and two large bones, the sacrum and the coccyx (often referred to as the "tailbone"). The cervical spine refers to the 1st through 7th vertebrae. It starts at the base of the skull and ends at the shoulders. The 12 thoracic vertebrae continue at the shoulders and end at the lumbar spine (5 vertebrae). In between each anterior vertebra is a cushion of fibrocartilage known as the *intervertebral disk*. Posteriorly, there is a bony arch that conveys and protects the spinal cord. The spinal nerves exit at each level to innervate the muscles and sensation to the shoulders, arms, and trunk. The stability of the spinal cord depends on the integrity of the anterior and posterior columns.

Clinical Evaluation

Field Evaluation and Early Treatment

Spinal injuries can be extremely serious. At the time of injury, a clinician (doctor, nurse, athletic trainer, emergency medical technician, etc.) needs to assess the degree of injury. In the case of an unconscious or obtunded athlete, spinal injury is presumed. In the conscious and alert athlete, any spinal pain, tenderness, or neurologic deficit will mandate appropriate spinal care. In these circumstances, it is important to use a well-practiced technique of immobilization on a spine board and transfer the patient to the nearest emergency department.

If the athlete is wearing a chin strap, helmet, and shoulder pads, it is best to leave these in place. The helmet is immobilized by taping blocks on the sides. However, prior to transport, the face mask should be removed to allow for airway management if this is needed. Helmet removal places the spine at risk unless the helmet is removed in unison with the shoulder pads in a well-rehearsed fashion.

For athletes without helmets and pads, the cervical spine should be immobilized by placing a hard cervical collar without moving the head.

History

The mechanism of injury should be determined from the patient's account and any available witnesses. The athlete will report any symptoms he or she is having, including pain at the site of injury; radiating pain that moves from the site of injury to other areas of the body; numbness or inability to feel in parts of the body, or a "tingling" or a feeling of "pins and needles," known as *paresthesias*; weakness of parts of the body; or an inability to move parts of the body.

Physical Examination

The physical examination will start with inspection, looking for swelling, bruising, abrasions, lacerations, or other evidence of injury. Next, palpation of the affected area, looking for warmth or areas of tenderness, is usually performed. The athlete may be asked to move various parts of the body, possibly pressing them against the examiner, who tries to resist the movement. This allows the examiner to gauge the patient's strength. Parts of sensation may be tested by asking the patient if he or she can feel the examiner lightly touching the patient or to distinguish between one and two sharp points. These tests give the examiner a sense of whether a nerve has been damaged.

Diagnostic Tests

The information obtained from the history and physical examination is used to decide whether any diagnostic tests are necessary. Plain X-rays are useful to determine many obvious fractures and misalignment. Computed tomography (CT) is very helpful in detecting occult fractures, while magnetic resonance imaging (MRI) is useful in detecting soft tissue and spinal cord injury. In children, an MRI scan is helpful in fractures because the bones have not fully calcified yet. Electromyograms and nerve conduction studies may be useful in assessing whether any nerve damage has occurred, but usually, these are not helpful in the first 2 weeks after injury.

Prevention of Injury

Many cervical and thoracic spine injuries can be prevented. Strengthening and increasing the flexibility of the muscles that support the spine can help in prevention. In addition, the athletic equipment used in various sports, particularly collision sports such as football and ice hockey, is designed to reduce the risk of spine injury, as well as other potentially catastrophic injuries. Perhaps, the most useful strategy for preventing cervical and thoracic spine injury is to develop safety rules and properly enforce them. A classic example of this is in

American (U.S.) football. Prior to 1976, players used to straighten their spine and head and strike their opponents with the crown of the head, a technique known as "spear tackling." This was disallowed in 1976. Since that time, the number of cervical spine injuries has decreased by approximately 66%.

Return to Sports

Returning to athletics after a cervical or thoracic spine injury depends on the type and degree of injury. These injuries may be chronic overuse or acute injuries. At a minimum, the patient should be symptom-free and able to perform the duties of his or her sport without having to change the technique. Unfortunately, some spinal injuries will preclude patients from athletics that pose an increased risk of contact or collision. Some specific injuries are discussed below.

Stingers and Burners

"Stingers" or burners are common in collision sports such as football and rugby. These injuries result from the nerves of the arm being stretched or compressed. The nerves that supply the arm originate from the spinal cord and course through the neck and down the arm. When an athlete is struck on the head, neck, or shoulder, the neck will often bend to the side. This results in stretching of the nerves on the side that is struck or compression of the nerves on the opposite side. When the nerve is damaged in such a way, it will often result in a burning or stinging sensation down the arm. In addition, the muscles of the arm and shoulder may become weak. Eventually, nerve function returns with normal sensation and strength.

Stingers or burners always occur in one arm only. If the same sensation develops in both arms or in one or both legs, it may indicate an injury to the spinal cord, and the athlete should seek immediate medical attention.

When burners or stingers occur, the athlete should be removed from play and examined by a clinician. Before returning to play, the athlete's symptoms must be completely resolved. The symptoms should have occurred only in one arm. There must be no remaining burning or stinging. There must be no tenderness or pain along the cervical spine or neck. There must be a full, pain-free range of motion of the shoulder, arm, and neck. And the athlete's original strength should have returned. The symptoms associated with burners or stingers usually resolve within 1 to 2 minutes. They may, however, persist for days to weeks. Persistent symptoms, recurrent injuries, symptoms in both arms, decreased pain-free range of motion, or decreased strength requires further evaluation.

Transient Quadriplegia

Transient quadriplegia is a type of neurapraxia or bruise to the spinal cord. It occurs in the cervical spine. This results in burning, tingling, or complete loss of sensation in the arms and legs, with associated weakness. At times, total paralysis may be seen. By definition, these episodes are temporary, lasting anywhere from 10 minutes to 2 days. X-rays will usually be normal. It is believed to occur as two of the bones within the spine pinch the spinal cord. These athletes should be evaluated by a spine specialist as they are at risk for permanent injury and return to play is doubtful.

Cervical Degeneration

Force repeatedly applied along the length of the spine can result in cervical degeneration. This can be seen in athletes who frequently employ "spear tackling." This behavior can lead to narrowing of the cervical spinal canal, the area in which the spinal cord resides. It can also result in straightening of the cervical spine from its normal curved structure. This is referred to as *loss of the normal lordosis*. This increases the risk of permanent nerve and spinal cord damage. These athletes should be removed from play until the normal curvature of the cervical spine returns.

Unstable Cervical Spine Fractures

The cervical spine is most at risk of fracturing when the head is flexed slightly forward, thereby straightening the normal cervical lordosis. Catastrophic cervical fractures with spinal cord injury occur when impact forces to the top of the head are applied in this flexed posture. The now illegal maneuver called "spear tackling" refers to an athlete straightening the spine and driving through an opponent head first. Similarly, the ice hockey player must practice "heads-up hockey" when going into the boards to avoid straightening the cervical spine.

Athletes with stable spine fractures that are proven radiographically to have healed and manifest no instability on dynamic flexion and extension lateral X-rays are often cleared for return to play.

Thoracic Spine Fractures

Although less common than cervical or lumbar (lower back) spine injuries, fractures of the thoracic spine do occur. They are associated with axial loading of the spine, when a force is applied to the length of the spine. Minimal fractures are braced for 6 to 8 weeks and then conditioned before return to play. Except for minimal fractures, advanced imaging with CT or MRI may be needed to confirm cord stability.

Scheuermann Kyphosis

This is an injury pattern of adolescence. The growth cartilage of the vertebral bodies becomes more compressed, causing a humped back (forward-flexed thoracic spine). It is important to detect as it is reversible if spinal growth remains. If detected while the athlete is still growing, extension strengthening and bracing may be effective in correcting the posture.

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See also Back Injuries, Surgery for; Cervical and Thoracic Fractures and Traumatic Instability; Cervical Brachialgia; Emergency Medicine and Sports; Fieldside Assessment and Triage; Neck and Upper Back Injuries; Spinal Cord Injury

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Cervical Brachialgia

Cervical brachialgia is a term that is not commonly used in the modern medical literature. It alone is not a specific diagnosis but refers to pain in the area of the neck or shoulder that may radiate down the arm. Cervical brachialgia is due to irritation of the nerves of the arm, somewhere between their origin in the cervical spine and their ultimate position in the arm.

Anatomy

The nerves that supply the arm originate in the brain. The nerves supplying the right arm start in the left side of the brain, and vice versa. They leave the brain and travel down the spinal cord, a collection of nerves enclosed by the bones of the vertebral column. These bones, the vertebrae, are made up of an anterior vertebral body and a posterior bony arch. The vertebral bodies are separated by the intervertebral disk. The posterior arch articulates with the vertebrae above and below by two facet joints. At each level, a nerve exits to innervate a specific muscle group and sensory pattern. These nerves exit in the nerve tunnels formed by the disk in the front and the facet joints behind. There are seven cervical vertebrae and eight cervical nerves (C1-C8). The cervical nerves emerge above their corresponding vertebrae, except for C8, which exits below the seventh vertebra. For example, C3 exits between C2 and C3. This is distinct from the thoracic and lumbar spine, where the nerve exits below its named vertebra.

The lower part of the cervical spine comprises the nerves that form the brachial plexus. The brachial plexus innervates the shoulder and the arm. These nerve roots include C5, C6, C7, C8, and T1. From here, they travel through a series of muscles called the scalene and then underneath the collar bone, or clavicle, and into the upper part of the arm, making their way down the arm and ultimately to the hand. The arteries and veins to the arm follow a similar pathway and may also be involved.

Clinical Evaluation

History

Patients may complain of pain in the neck and shoulder and down the arm. The symptoms are usually only on one side. The pain may continue into the fingers. At times, it may involve the upper back and chest as well. It may be described as a sharp, stabbing, or burning sensation or numbness. It can be exacerbated by changes in position. There may be a history of sports activity, such as in the throwing athlete. There may also be a known acute traumatic event, such as a fall on the shoulder. However, there may be no preceding overuse pattern of injury. The pain may precede the neurologic symptoms of numbness or weakness, which may confuse the initial diagnosis.

Physical Examination

Patients with cervical brachialgia often hold their heads flexed forward. The muscles of the neck and shoulder are often in spasm and can be tender to the touch. The range of motion of the neck may be limited. Most of the time, they will not have tenderness over the bones of the spine, or vertebrae. A thorough neurologic examination is important. However, the initial neurologic findings may be minimal to none and can lead the examiner to feel that there is a muscle overuse injury pattern. Once the neurologic manifestations occur, there may be weakness of the shoulder girdle muscles, such as the deltoids, as well as the muscles of the arm, wrist, and hand.

Diagnostic Tests

There are some tests that might be useful in discovering the cause of cervical brachialgia. Potential causes of cervical brachialgia are discussed below. X-rays may show abnormalities of the bones, arthritis, or fractures that are contributing to the patient's symptoms. They may also reveal whether a cervical rib (see next section) is adding some compression to the nerves as they exit the shoulder. A chest X-ray will indicate if there is a cause from the upper chest.

Computed tomography (CT) may be useful in the posttraumatic setting to better detect fractures and misalignment. It may help in detecting any degenerative changes of the facet joints as well.

Magnetic resonance imaging (MRI) allows physicians to see abnormal positions of the disks, tumors, and other soft tissues that might be affecting the nerves. At times, there are fibrous bands that may also compress the nerves. It is important to perform MRI scans in functional positions of compression. Many overhead athletes will have normal anatomy until the arm is placed in a functional position of compression. This refers to the arm being held out in an externally rotated position to detect impingement of the nerves and vessels. If done in this manner, MRI scans may also show the blood vessels and any aneurysms causing pain.

Electromyography and nerve conduction tests are often useful in delineating a compressed nerve in the shoulder girdle. They will be normal when the cause is more central in the spinal canal. These studies are not usually useful in the first few weeks.

Potential Etiologies

In some patients, cervical brachialgia results from the presence of a "cervical rib." A cervical rib is an extra rib that arises from the portion of the spine in the neck, as opposed to the normal thoracic spine in the chest. This extra, or "supernumerary," rib may compress the nerve as it exits the spinal cord in the neck and travels down the arm.

For other patients, arthritis or degeneration of the joints between the bones of the spine may result in similar pinching or impingement on the nerves, resulting in pain. A frequent cause of this is facet joint degeneration, which impinges on the exiting nerve. The swelling or displacement of bones that is associated with fractures that have healed may result in similar irritation. The intervertebral disks may degenerate near the exiting nerve and cause gradually increasing irritation to the exiting nerve. Alternately, acute herniated disks may compress the nerve, resulting in shoulder pain.

Tumors in the brain or spinal cord may produce cervical brachialgia by interfering with the normal processing of the nerve. Tumors of the upper chest may also manifest with brachialgia. Aneurysms, a ballooning outward of the walls of the arteries, may also press against the nerve and cause cervical brachialgia.

A bacterial abscess around the spinal cord (epidural abscess) is an uncommon but potential cause of brachialgia. Systemic disease, such as temporal arteritis or lymphoma, may also cause these symptoms in the older athlete. Finally, there are postviral syndromes that mediate a presumed abnormal immunologic response whereby the body temporarily attacks the cervical nerve roots. This is called Parsonage-Turner syndrome. This may cause pain and weakness of the shoulder and arm.

Sometimes, simple muscle tendon overuse may produce brachialgia. Common offenders are the trapezius from the top of the scapula to the spine as well as the levator scapula, the muscle from the upper, inner scapula to the cervical spine.

Treatment

Cervical brachialgia is addressed by first defining the etiology and treating the underlying cause. Some mechanical issues such as spinal degeneration are treated with physical therapy aimed at strengthening the neck muscles and upper trunk postural muscles. Surgical options are possible for significant nerve impingement or for addressing more ominous causes such as tumors. When muscle tendon overuse is detected, the sport-specific biomechanics must be addressed, along with a full, closed-chain analysis to detect weakness more proximally on the kinetic chain (muscle linkages from the legs through the back to the shoulder). When the diagnosis is felt to be a postviral syndrome, the athlete is encouraged to strengthen the surrounding unaffected muscle groups while waiting for the nerves to recover.

Return-to-Sports Criteria

The athlete's return to competition is highly dependent on the cause of the cervical brachialgia. It also depends on the sport played. For contact sports, the athlete must manifest a full cervical range of motion and a normal neurologic examination, including regaining of original strength and the absence of pain. If surgical interventions are undertaken, the athlete must demonstrate the same as well as surgical stability of the spinal cord in the appropriate cases. For noncontact activity, the athlete should minimize overhead activity until the shoulder girdle, including the rotator cuff, is strong enough to protect the shoulder from further injury.

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See also Cervical Disk Degeneration; Cervical Facet Syndrome; Neck and Upper Back Injuries; Neck Spasm; Shoulder Impingement Syndrome; Torticollis, Acute

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Cervical Disk Degeneration

Neck pain is a common musculoskeletal complaint. It affects at least 50% of the population over a life span. There are multiple causes of neck pain, but the cervical disk is a very common source. The disk is the cushion pad between each vertebral body, as described below. The cervical disk may degenerate as part of the normal aging process without any symptoms. *Degeneration* describes the natural process of disk dehydration, with consequent loss of height. Under the age of 40, magnetic resonance imaging (MRI) may show degenerative disk changes in 25% of the population. Over the age of 40, these changes are noted in at least 60% of people and often without any symptoms.

A number of factors have been related to cervical disk degeneration, including genetics, smoking, a sedentary lifestyle, repetitive motion, and nutrition. Athletic activity certainly may contribute to the process, such as head impacts in football and rugby. Neck hyperextension in competitive cycling is another mechanism with a shear force to the disk.

Anatomy and Pathology

The cervical spine is similar to the lumbar and thoracic spine, with the anterior vertebral bodies separated by the intervertebral disk and a posterior bony arch containing the spinal cord. The posterior arch is separated from the contiguous levels by two facet joints at each level (Figure 1). The facet joints in the cervical spine are unique, with a horizontal plane that allows a large amount of head rotation.

The disk is composed of an outer ligamentous annulus. This is a well-organized series of collagen layers that surround the gelatinous and highly aqueous nucleus pulposus (Figure 2). The nucleus has multiple substances that are highly inflammatory when exposed to the nerve roots. The purpose of the disk is to allow for shock absorption and fluidity of motion. The degenerative process of the disk involves gradual disk dehydration with loss of disk height and increasing spinal stiffness. This is due to gradual fissuring of the annulus and loss of the gelatinous nucleus, resulting in more contact with the bony prominences of the vertebrae with spur formation.

A unique anatomical finding in the cervical spine is a bony prominence on the posterior part of the vertebral body called the uncinate process (Figure 3). During childhood, this forms an articulation with the vertebral body above and is referred to as the joint of Luschka. As it is positioned in front of the spinal nerve exit (neuroforamina), degeneration here may cause a bone spur foramation impinging the nerve from the front. The facet joint is just posterior to the spinal nerve. As the disk height collapses, facet joint degeneration occurs with spur formation and impingement of the exiting nerve from behind. Each spinal nerve exits in the canal formed by its vertebrae and the upper contiguous vertebrae. For instance, the sixth cervical nerve (C6) exits from the C5-C6 foramina, while C7 exits from C6-C7.

Disk degeneration is often asymptomatic and of no clinical significance. However, the disk degeneration may cause symptoms by several mechanisms. If the degeneration is more rapid and there has not been time to develop the stabilizing bony

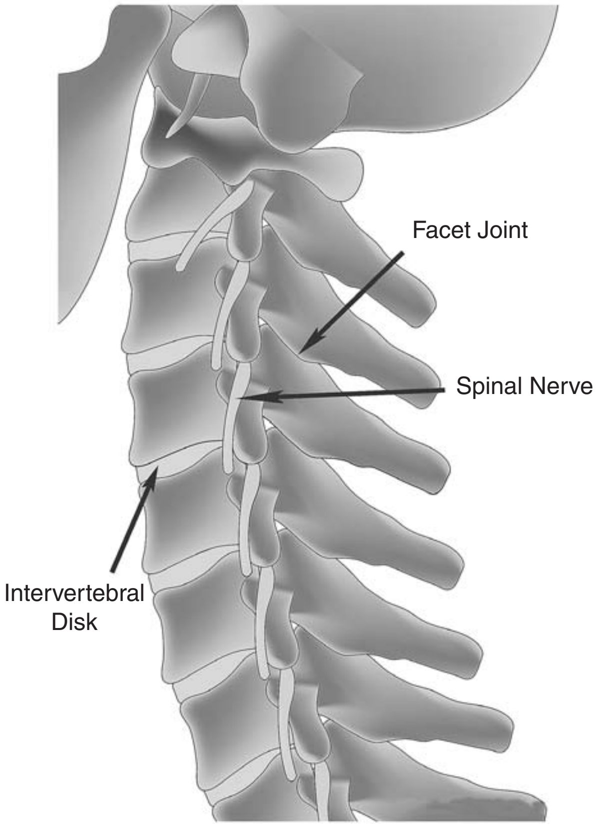

Figure 1 Cervical Spine, Showing Facet Joints and Intervertebral Disks

Source: Illustration by Michael d'Hemecourt.

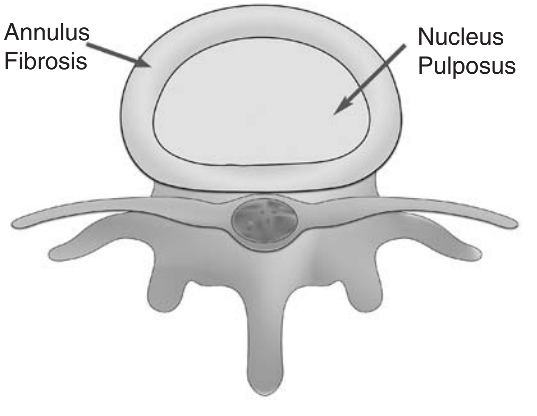

Figure 2 Anatomy of an Intervertebral Disk (as Seen From Above)

Source: Illustration by Michael d'Hemecourt.

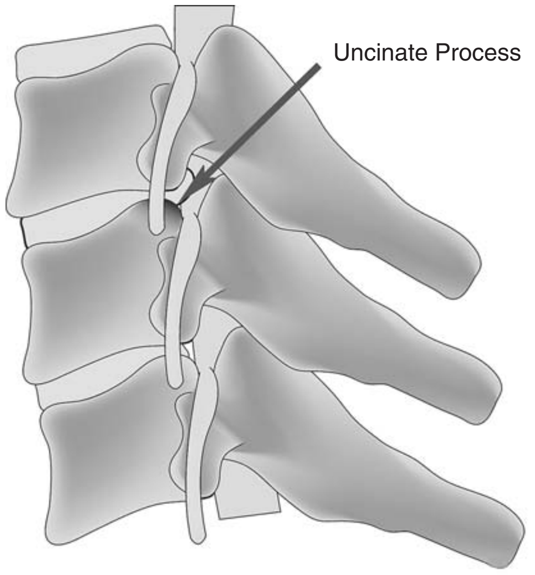

Figure 3 Side View of Cervical Spine Showing Position of Uncinate Process

Source: Illustration by Michael d'Hemecourt.

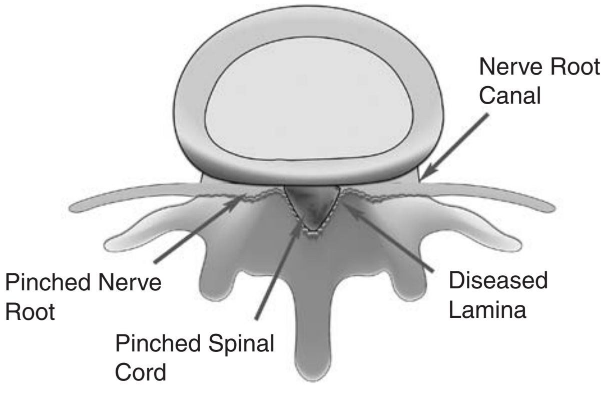

Figure 4 Mechanism of Nerve Impingement in the Spinal Column With Spondylosis

Source: Illustration by Michael d'Hemecourt.

spurs, instability may occur with excess motion. A second mechanism is an internal disk derangement. Here, there is no outward abnormality of the disk. The fibers of the annulus suffer microtears near the outer edge of the disk, which has a density of pain fibers. Often, no findings are seen on an MRI scan. These two mechanisms cause central neck pain without radiation.

The third mechanism involves nerve impingement with peripheral symptoms (radicular symptoms). The diffuse degeneration of the disk and bony prominences is often referred to as *spondylosis,* which may lead to *stenosis,* a narrowing around the nerves. Stenosis is subdivided into lateral stenosis, around the exiting nerve roots, and central stenosis, which is narrowing in the spinal canal around the spinal cord (Figure 4). Lateral stenosis may result in radicular symptoms of pain and weakness into the upper extremity. This is often reversible. Conversely, central stenosis may cause irreparable degeneration of the spinal cord, referred to as *spondylolytic myelopathy*. The spinal cord has no regeneration potential for nerve injury.

Clinical Presentation

Athletes with cervical disk degeneration may present with neck pain only. There is often pain with certain motions, such as heading the ball in soccer or sustaining impact from a football. Pain may also be further aggravated in certain postures, such as computer keyboard work with extreme cervical hyperextension. The physical examination often reveals diminished range of motion and tenderness of the facet joints, as these are easily palpated off the midline of the posterior cervical spine. Pain may be aggravated in neck flexion and extension.

When the spinal nerves are inflamed or impinged, there is radiation down a specific pattern into the upper extremities. For instance, the sixth cervical nerve will send pain to the thumb and outer aspect of the forearm. The interscapular region is also a common area of pain radiation from multiple levels. Radicular symptoms are often exaggerated with a Spurling maneuver. Here, the athlete is asked to extend the neck and rotate to the involved side. With lateral stenosis, the radicular symptoms will be reproduced. The same radicular symptoms are often relieved with arm elevation on the affected side. It is very important to perform a thorough neurologic examination.

Players of contact sports, such as football and rugby, will often experience a stinger syndrome with transient pain, numbness, and weakness in the arm. In the adolescent athlete, this is usually a stretching phenomenon of the nerves as they traverse the shoulder. Conversely, in the college and professional-level athlete, there is often compression in the neuroforamina due to some ongoing lateral stenosis.

Finally, chronic central stenosis may cause spinal cord degeneration, or myelopathy. Patients will present with an unsteady gait and diffuse weakness of the upper and/or lower extremities. There may also be a loss of ability to hold bowel or bladder function. Hyperreflexia and spasticity may also be seen.

Evaluation

Plain radiographs are critical to look for loss of disk height and instability. Lateral views with flexion and extension are best to detect instability. This would be manifested by one vertebra moving more than 3 millimeters (mm) over the lower vertebrae on flexion and correcting on extension. MRI is very valuable for contact sports as it will detect disk involvement and any related spinal stenosis. The normal canal diameter should be 12 mm. Occasionally, dynamic MRI with flexion and extension will reveal functional stenosis not present in the neutral position.

Since there may be multilevel disk degeneration with peripheral symptoms, electromyograms (EMG) and nerve conduction studies may be helpful in delineating the exact level of involvement. However, EMGs are very good at detecting muscle weakness but not very helpful with sensory changes.

Treatment

Conservative management is usually effective with cervical disk degeneration, particularly with nonradiating pain syndromes. The natural history of radicular symptoms is also quite good and is also usually treated nonoperatively. During the acute phase, analgesics are prescribed with 3 to 4 days of rest. Use of a cervical collar should be limited to a maximum of 4 days. During the acute and subacute phases, modalities such as traction preceded by muscle relaxation through heat application may be very helpful. Once the symptoms have begun to abate, upper trunk postural stability is initiated along with aerobic conditioning. Once the peripheral symptoms have resolved, cervical strengthening is also undertaken.

Medications that are most helpful are nonsteroidal anti-inflammatories, mild analgesics such as tramadol, and sleeping aids. Sleeping aids may include the muscle relaxant cyclobenzaprine or tricyclic antidepressants. Corticosteroids (such as a 7-day prednisone taper) can be very helpful in relieving the radicular symptoms, and epidural corticosteroid injections are also quite effective.

Complementary assistance with acupuncture, mobilization, and massage may be effective in the short term, although it is without proven long-term benefits.

Surgical intervention should be considered if there are progressive neurologic deficits, bowel/bladder dysfunction (emergent), and symptoms refractory to conservative care.

Return to Sports

Athletes with cervical disk degeneration frequently have concerns about return to play. For noncontact sports, the questions usually involve function and pain tolerance. Exercise is important for spinal health and is encouraged. The more significant question is return to contact sports and the risk of catastrophic nerve injury. The presence of disk degeneration or herniation is not a problem as long as symptoms have resolved and there is full range of motion and neurologic function. If the athlete has central spinal stenosis and transient neurologic symptoms that have cleared, there remains a relative contraindication to return until the stenosis has been resolved surgically. A single-level fusion is not a contraindication for contact sports but a two-level fusion is a contraindication.

Pierre A. d'Hemecourt

See also Back Injuries, Surgery for; Cervical and Thoracic Disk Disease; Cervical Brachialgia; Intervertebral Disk Disease; Lower Back Injuries and Low Back Pain; Pain Management in Sports Medicine; Slipped Disk

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Cervical Facet Syndrome

Neck pain is a common musculoskeletal complaint with a prevalence that has been estimated to be 14% or higher. Neck pain can be divided into two types: (1) those syndromes that cause central neck pain (axial pain) and (2) those that cause pain radiation to the extremities or neurologic injuries. The causes of neurologic injuries include disk herniation and severe narrowing around the nerves in the spinal canal or in the nerve channels (neuroforamina), where the nerves exit the spine. These nerve injuries are discussed in other entries of this encyclopedia.

Axial pain syndromes are caused mostly by mechanical problems of the soft tissues or bony articulations, such as unstable disk degeneration, also called *degenerative disk disease*. Several joints in the cervical spine also may cause pain due to degeneration. These joints are articulation points between the vertebrae above and below. They are the facet joints on the back of the spine and the uncovertebral joints on the front of the spine (Figure 1).

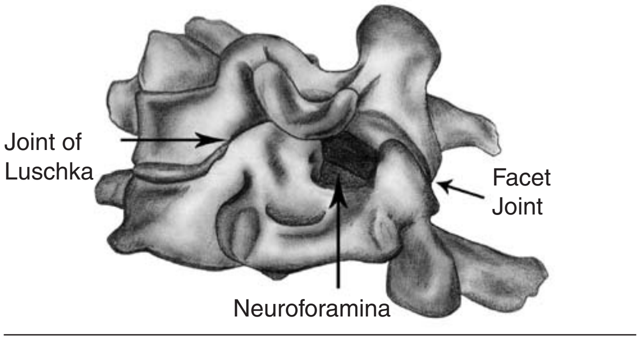

Figure 1 Cervical Vertebrae, Lower Cervical Spine

Source: Illustration by Michael d'Hemecourt.

Facet joint pain is one of the most common causes of axial pain generation. Other causes of axial pain include cervical spondylosis, which is a diffuse degeneration including the disk, as well as bony structures such as the facets. Whiplash syndrome is another cause of axial pain, most commonly due to injury to the facets, but it may involve the disk and some ligamentous structures. Myofascial pain involves tight painful muscle bands with trigger points. This may be related to fibromyalgia. Finally, certain rheumatologic diseases may be responsible for axial neck pain. Rheumatoid arthritis, spondyloarthritis, and polymyalgia rheumatica are some examples. They are often associated with other systemic manifestations of joint and muscle pain.

Anatomy and Biomechanics

The cervical spine may be viewed as the upper and lower cervical spine because of significant differences in anatomy between the two. The upper cervical spine (Figure 2) involves the atlas (C1) and the axis (C2). The atlas articulates with the occiput by two concave joints upward. This articulation allows much flexion and extension (nodding) as well as lateral flexion. The atlas is the most unusual as it is without a vertebral body. The body has become part of the axis called the *dens* or *odontoid process*. The dens articulates with the atlas and is held in place by the transverse atlantal ligament. This allows for about 50% of the cervical rotation.

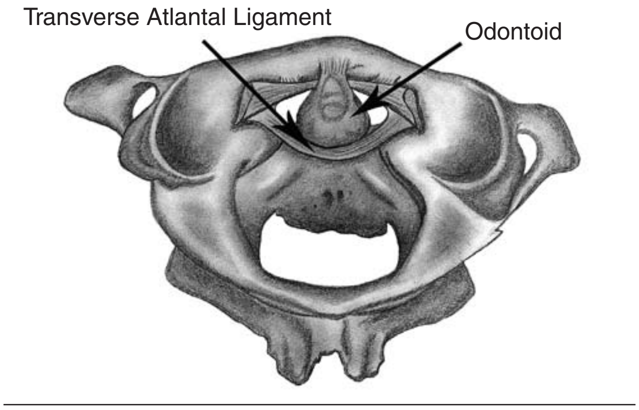

Figure 2 Upper Cervical Spine, Showing Atlanto-Axial Articulation

Source: Illustration by Michael d'Hemecourt.

Below C2, the vertebral bodies are separated by the intervertebral disk anteriorly and the facet joints posteriorly. The facet joints are also called the zygapophyseal joints and are named by the levels that articulate, such as C2-C3. These are located just posterior to the neuroforamina for the exiting spinal nerves (see Figure 1). Facets are normal joints lined with hyaline cartilage on the surfaces, a joint capsule for stability, and synovium to produce the synovial fluid. The cervical vertebral bodies are also unique because of the shape at the top, which is concave upward, while the vertebral body above has a depression to allow for this. By the age of 8, this becomes an articulation similar to a joint and is called the joint of Luschka, or the uncovertebral joint. Note that this is just anterior to the neuroforamina. Degenerative processes of the facets and uncovertebral joints may encroach on the exiting nerve roots.

In the cervical spine, the facet joints are in a more horizontal plane, at about 45° from the horizontal. This allows a coupled motion of lateral flexion and rotation. When there is lateral flexion to one side, there is a simultaneous rotation to that side.

As previously mentioned, degenerative processes of any of these structures can cause axial pain. However, several studies that have differentiated chronic cervical pain, by applying anesthetic injections selectively, demonstrated that the facets may be responsible for up to 60% of chronic cervical pain. Similar selective injection studies on patients with more than 3 months of cervical pain from a whiplash type of mechanism also demonstrated the facet joint as a predominant area of pain generation. Other areas of pain generation were tears to the ligaments of the disk and ligaments from the dens to the occiput (alar ligaments).

Clinical Presentation

Cervical facet syndrome can present with an acute extension or rotational injury as well as a chronic overuse pattern. In the acute setting, an athlete may present with acute pain, spasm, and tenderness of the facet joints. There may be a transient "stinger"-type syndrome due to the involved nerve compression anterior to the facet joint. The athlete will often be limited in extension. The Spurling maneuver—extension and rotation of the spine to the affected side—will often cause neck pain.

In the chronic setting, there is often a limitation to a full range of motion, especially in extension. Settings that often increase the cervical lordosis or extension, such as keyboard work, may aggravate the pain. With the athlete supine and the cervical muscles relaxed, the facet joints are usually easily palpated for specific tenderness at the affected level. The neurologic examination is often normal unless there is an associated injury with instability.

Facet joint pain has characteristic referral patterns depending on the facet level involved. This has been demonstrated by provocative injections into facet joints. The C2-C3 facets refer pain to the occiput and upper neck. C3-C4 facets refer pain to the posterior neck, while C4-C5 facets refer pain to the upper shoulder. C5-C6 facets also refer pain to the shoulder and upper scapula. Pain in the lower scapula is referred from C6-C7.

Evaluation

The evaluation of facet pain in the athlete usually requires ruling out other diagnoses as well as instability. A magnetic resonance imaging (MRI) scan may show some associated disk degeneration that is often not significant. In the acute setting, a computed tomography (CT) scan may show an occult fracture or a partial dislocation of a facet joint. Dynamic lateral radiographs in neutral, flexion, and extension are often needed in the contact athlete to ensure that there is no instability. This would be manifested by more than 3.5 millimeters (mm) of translation on these dynamic studies or more than 11° of angulation.

In an athlete with a stinger-type injury that coexists, MRI should be considered if the symptoms last for more than a few minutes or if there are any associated bilateral or leg symptoms. Dynamic lateral radiographs should also be done. Electromyography is considered if there are persistent neurologic symptoms.

Treatment

Rehabilitation is divided into acute, subacute, rehabilitative, and sports-specific phases. During the acute phase of the first few days, use of ice and minimal mobilization are appropriate. Modalities such as ultrasound and cryotherapy may serve well here. After the first few days, the athlete is started on some upper trunk postural stability and isometric strengthening for the cervical spine. The longest phase is the rehabilitative phase, for progressive strengthening of the upper trunk as well as the cervical spine muscles as tolerated. Resisted chin tucks are often well started at this phase. The sports-specific phase will gradually reintroduce the motions that are required by the sport, and that may be aggravating. It is important to look at sports-specific techniques.

Medications can often be helpful. Since there is often an associated inflammatory component, anti-inflammatory medication is very useful for a short course. If sleep is a problem, a tricyclic antidepressant such as amitriptyline is useful. If there is a neuropathic pain component, antiseizure medication such as gabapentin may be helpful.

Facet manipulation using osteopathic mobilization may be very helpful. This will often involve muscle energy techniques. Acupuncture can also be a strong complementary addition to the care of cervical spine pain.

More invasive interventions are usually withheld for refractory cases. Corticosteroid injection into the cervical facet joints is not strongly supported in the literature. However, diagnostic anesthetic blocks of the median nerve branches that innervate the joints may indicate that a radiofrequency neurotomy be done percutaneously. This involves burning the sensory nerves and may provide relief for 6 to 9 months. This is not a common procedure for an athlete.

Return-to-Sports Criteria

For the athlete involved in a collision sport, it is important to perform the imaging studies mentioned above to rule out instability or significant encroachment on the spinal canal. Even with normal studies, the athlete should also demonstrate a normal neurologic examination, full range of pain-free motion, and normal biomechanics of cervical spine motion.

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See also Back Injuries, Surgery for; Cervical and Thoracic Disk Disease; Lower Back Injuries and Low Back Pain; Musculoskeletal Tests, Spine

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Cervical Nerve Stretch Syndrome

Cervical nerve stretch syndrome is a fairly common sports injury resulting from trauma to the shoulder or neck. It is an injury to the upper extremity peripheral nerves, manifested most commonly as a shooting or burning pain that radiates down the arm on the affected side (hence the terms *stinger* and *burner*). It is most frequently reported in football players but can also occur in those participating in cycling (in crashes), ice hockey, gymnastics, wrestling, and other contact sports.

Anatomy

The *brachial plexus* is a network of nerves that originate from the lower cervical and upper thoracic portions of the spinal cord to provide motor and sensory innervation to the upper extremities (one on each side for each arm). The plexus starts off as the five nerve roots (C5, C6, C7, C8, and T1) exiting from the spinal canal. C5 and C6 combine to form the superior trunk, C8 and T1 form the inferior trunk, and C7 is renamed the middle trunk. From there, each trunk splits into an anterior and posterior division. These six divisions are then regrouped into cords. The posterior divisions of all trunks form the posterior cord, the anterior divisions from the superior and middle trunks form the lateral cord, and the remaining anterior division of the inferior trunk is renamed the medial cord. Along the way, through this organization and reorganization of the nerve roots, several nerves arise to provide specific motor and sensory information to the arm and hand. This complex arrangement of the innervation explains the generalized nature of the symptoms of a stinger.

Pathophysiology

The injury is typically the result of a traction or stretch mechanism applied to the neck and/or shoulder. Sometimes direct trauma to the area can elicit similar symptoms. Football seems to be the most common sport in which this injury takes place, since players frequently apply traction on each other in blocking and tackling. A similar mechanism can occur when falling to one's side, particularly at speed. For example, as a crashing cyclist hits the ground, one's shoulder may be drawn down toward the feet while the head is pushed to the other direction, stretching the brachial plexus from both ends. Although less common, direct trauma can cause similar symptoms by "bruising" the nerves of the plexus or by compressing them through swelling of the surrounding soft tissue.

The most common symptoms of cervical nerve stretch syndrome are burning and/or shooting pain radiating down the arm and into the hand, similar to when one's arm has "fallen asleep." However, depending on the severity of the injury and what parts of the plexus are affected, there may also be associated numbness or weakness in the arm and hand. Depending on severity, symptoms may last anywhere from a couple of minutes to several weeks. However, a burner or stinger does not usually lead to permanent deficits.

Diagnosis

Sometimes, a burner can be diagnosed before a player even approaches a physician or athletic trainer. Frequently, immediately after the injury, a player may shake his or her arms as if to try to "wake up" the limb. Otherwise, history and physical exam are key. Before that, however, the examiner should make sure that the athlete's cervical spine is stable by asking appropriate questions regarding neck pain and examining the neck. If stable, the examiner may proceed; otherwise, cervical spine immobilization should be applied immediately.

It may be difficult to elicit specific details leading up to the injury, but a general sense of how the player was hit or fell coupled with a description of subsequent symptoms should lead one toward a diagnosis of cervical nerve stretch syndrome. It is important to get as much detail as possible with regard to symptom history, as this may help in estimation of recovery time, management, and evaluation of progress.

The physical exam should be detailed as well. First, inspect the affected and unaffected sides for asymmetry of musculature that might indicate previous injury or increased risk for injury (decreased muscle mass may allow for more traction to occur by not providing enough counteractive reflex contraction). Palpation of the shoulder and clavicle should be performed to rule out more serious injuries such as dislocation or fracture, especially if visual inspection reveals an obvious deformity. Next, if the cervical spine has been cleared, assess the neck in a more detailed fashion for range of motion, paying particular attention to maneuvers that trigger symptoms. Special maneuvers such as the Spurling test or Tinel sign may give clues as to where in the plexus the injury has occurred.

Of particular importance are motor and sensory exams to attempt to uncover any specific deficits that may point to a particular nerve or nerve root. Again, these findings also have implications in management and monitoring progress. In particular, one can test every nerve root of the brachial plexus with a detailed motor exam.

Although an X-ray would be useful if a fracture is suspected, imaging is generally not indicated in the acute phase. However, X-rays of the cervical spine may uncover underlying conditions, such as arthritis or neural foraminal narrowing (the openings in the spinal column where nerve roots exit the vertebral canal), that could augment the symptoms of cervical nerve stretch syndrome. A magnetic resonance imaging (MRI) scan might be indicated if involvement of the spinal cord, rather than simply the nerve roots or plexus, is suspected.

Also potentially useful is electromyography (EMG), a test that evaluates nerve conduction and, as such, may help define the location and severity of the injury. EMG testing should be limited to patients with persistent symptoms lasting 3 or more weeks. If performed before this time, testing may be falsely negative, since conduction delays can take several weeks to appear on EMG testing.

Management

Apart from pain control measures such as medication and rest, management focuses on prevention as recurrences are common. The first focus is improving flexibility and strength of the neck, shoulder, and arm. The left and right sides should be treated equally as any predisposing condition could be present bilaterally and to prevent creating any new asymmetry. A physical therapist might best be able to work closely with the patient in establishing an effective rehabilitation plan.

An emphasis on proper posture in daily activity might help minimize symptoms. Specifically, maintaining a head-up and chest-out posture helps reduce compression at the neural foramina in the neck and opens the thoracic outlet (the passage between the chest and neck used by the brachial plexus as well as several blood vessels).

In collision sports such as ice hockey and football, where pads are part of the requisite gear, additional safety equipment may be helpful in reducing the risk of injury. Lifters or extra air pads can be placed under shoulder pads to elevate them into a position to limit excessive flexion and extension of the neck and, thus, reduce the risk of sustaining a stinger. Care must be taken to ensure that the shoulder pads fit well and will stay in proper position through multiple collisions to prevent other injuries from occurring. Another alternative is a neck roll, a soft supplemental collar that attaches to the top of the shoulder pads. Again, the goal is to reduce excessive flexion and extension of the neck; however, installation is easier, with less shoulder pad adjustment required. A third device that to some degree applies both principles is the cowboy collar. This is a device that fits underneath the shoulder pads and secures separately to the chest (providing some shoulder pad elevation in the process) and incorporates a firm, raised collar that rises above the shoulder pads, engaging the sides and back of the helmet to guard against excessive neck motion.

All these devices have been shown to reduce excessive flexion and extension. As such, a decision as to which device to use should be player specific, taking into account player comfort, predisposition to injury, the position played, and the amount of head and neck mobility required to play at an optimal level, as well as the potential risk for other injuries in general due to reduced visibility (e.g., a player not being able to prepare for a hit because he or she isn't able to scan his or her surroundings).

Prognosis and Return to Sports

The symptoms of a burner can last several minutes to several weeks. A key determining factor in duration of symptoms is the degree of injury. The nerve is made up of neurons (nerve cells) and myelin cells, which surround and protect the nerve cells in the form of a sheath. These can be thought of as an electrical wire and the surrounding insulation, respectively. In a burner that lasts only minutes, the likely injury is a stretch to the nerve momentarily disrupting conduction without damage to either type of cell. In a Grade 1 injury, the myelin cells are damaged with little or no damage to the nerve cells. That is, the insulation is cut, exposing the electrical wire and creating a short circuit. The sheath is able to repair itself over time, and as such, symptoms will resolve over days to weeks. A Grade 2 injury of the nerve involves damage to both the myelin sheath and the underlying nerve cell but with preservation of other connective tissue structures. With the connective tissue structure intact, the nerve is able to regenerate in the correct location to resume function; however, this may take longer than recovery from a Grade 1 injury as peripheral nerves grow at a rate of only 1 millimeter/day (mm/day). A Grade 3 injury is complete disruption of the myelin sheath, nerve cells, and surrounding support structure. Without the connective tissue or myelin to guide it, the separated ends of the nerve cells cannot find each other to reconnect, so this is considered a permanent injury to the nerve, from which recovery of function is not possible. This is fortunately a rare occurrence in sports and actually would not be considered a burner or stinger. In addition to their particular symptoms, burners and stingers are partially defined by being temporary conditions.

Regarding return-to-play decisions, the keys are frequent reexaminations and resolution of symptoms. For a first-time injury, it is prudent to keep a player out for the remainder of that practice or competition, even if symptoms resolve quickly, until a more in-depth evaluation of technique, anatomy, and other predisposing factors can be performed. The athlete should be reexamined weekly to ensure improvement of symptoms. Once the symptoms have resolved, and not before then, a player can be cleared to return in a graduated fashion, starting with conditioning and progressing to full practices and then competition. However, regular reexamination should continue, and symptom recurrence needs to be addressed through physical therapy, technique and posture analysis, and equipment changes. In addition, participation needs to be reduced or withheld in case of symptom recurrence.

Unfortunately, even after careful rehabilitation, recurrence is common. Although permanent damage from recurrent burners is unlikely, they sometimes occur with increasing frequency or with progressively lesser insults. If this is the scenario despite proper management, a player may need to weigh the risks and benefits of continued participation. This last point highlights the importance of early detection of high-risk athletes to initiate a prevention plan.

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See also Cervical and Thoracic Spine Injuries; Football, Injuries in; Spinal Cord Injury

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Cheerleading, Injuries in

Cheerleading, defined as an athletic activity by the American Association of Cheerleading Coaches and Administrators (AACCA), is a unique combination of athletic ability, strength, and spirit that exists both as a school-related activity and as an independent, competitive industry for both youth and adult participants.

The development of cheerleading, as it exists today in the United States, can be traced to the 1800s, starting as an organized yell at a Princeton University football game and later as a group of dedicated supporters yelling or "cheering" their football team in Minnesota. Throughout the years, it has undergone many changes, and today it most commonly exists as an integral part of the local, school, and professional sports climate. It also has a separate existence as an independent competitive athletic industry that developed in the 1980s, which makes up more than half of the estimated 3 million members of the cheerleading nation. Cheerleading has been transformed from an activity in which participants once stood at the base of the stands and led fans in vocal cheering to a strenuous physical activity that is part gymnastics and part dance and requires skill and agility to participate. With its growing popularity has come an increased awareness of the injuries sustained and the need for more stringent guidelines for its participants.

Organization

Traditionally, cheerleaders are the ever-present supporters of school, local, and professional football and basketball teams. Many people know someone who wanted to grow up to be a Dallas Cowboys Cheerleader or a Laker Girl. Children (both boys and girls) are introduced to the activity as young as age 5 or 6, and participation at the school level is often linked with social acceptance. With school-sponsored squads, often the cost of participation is included in the school's athletic program. Other forms of spirit organizations, such as pep squads, pom-pom teams, and twirlers, are not included in the activity of cheerleading.

Cheerleading as an independent athletic industry, however, is less well-known outside the sports community, but its popularity is increasing. Cheerleader organizations, developed in the 1980s, are fee based and extracurricular. The cost per participant can vary from several hundred to several thousand dollars and often does not include travel costs for local and national competitions among the different squads. This domain has grown into a multimillion-dollar industry and captures a wide audience through media and television exposure.

Nearly all organizations are structured to include a coach, team captain, cocaptain, and members. The coaches, usually an adult male or female with prior experience in the cheerleading activity, may be part of the school staff or hired independently. The level of training at the coaching level varies widely and is not regulated at most local or state levels. There are no federal regulations regarding the qualifications of coaches, and in many instances, it is a volunteer position. Coaches are responsible for designing practice routines and exercise regimens, and ensuring the safety of the members of the squad. They should also have training in first aid and a working knowledge of the anatomy and severity of injury. Guidelines, developed by the AACCA, exist, but their degree of enforcement is not known. Captains and cocaptains are participants, or members, of the squad who serve as leaders among their peer group and often are responsible for major decisions made within the squad. They often run practice time and drills prior to sporting events or competitions and determine the members of the squad through tryouts.

Terminology

With the development of cheerleading has come descriptive terminology for the various positions and maneuvers, including, but not limited to, the following:

Maneuvers

Squads: Groups of participants, consisting of both male and female members

Members: Individuals in the squad

Routine: a sequence of moves, usually a choreographed dance combination

Stunt: a maneuver requiring tumbling, mounting, or tossing

Tumbling: forward or backward rolling or flipping

Flying: a skill in which a member is thrown or "tossed" into the air by a vaulter

Vault: using one's hands to propel a member into the air

Pyramid: a stunt involving multiple base members and flyers (may be more than the height of two persons)

Toss: to disengage a member from either a pyramid or a base arrangement

Mount: a skill in which a person is supported by the base (can be more than one person's height)

Dismount: to return all members to floor position

Positions

Base: bottom person in a stunt

Flyer: person who is elevated into the air or thrown from a mount

Spotter: person who helps with persons mounting or dismounting

An understanding of these terms is essential while assessing injuries incurred by those participating in this activity.

Controversies and Injuries

As an athletic activity, routines require skill in dance and gymnastics combined with strength and agility. Participants undergo rigorous training, not unlike that expected of other athletes in competitive sports. Because cheerleading is not governed by any regulated sports commission, there are no rules as to how many hours a squad can practice or how strenuous the training should be. Lack of classification of this activity as a "sport" may have also hindered accurate reporting of injuries sustained during participation. Over the past several years, the complicated routines that make cheerleading unique have come under scrutiny. This is largely due to an increase in the report of injuries to the National Electronic Injury Surveillance System (NEISS) and the National Center for Catastrophic Sports Injury Research (NCCSI). These data were then published in the *American Journal of Sports Medicine* in 2003, bringing public awareness to the inherent dangers of this activity. Many of these injuries were found to be associated with risky maneuvers that were being performed by participants whose level of training was not quantifiable. While these data were reported by participants in school-related cheerleading organizations, they may grossly underrepresent the actual number of injuries sustained by participants of the independent side of this activity. Advocates for regulation of the activity founded AACCA and the National Cheer Safety Foundation (NCSF), which put forth guidelines for coaches and participants in an effort to make cheerleading safer. These guidelines suggest appropriate trainer requirements and certification, safety measures for the use of mats and thickness of mats, and possible limitations on the height of tosses and pyramids. Other well-established organizations, such as the National Cheerleaders Association (NCA), have adopted these guidelines and also serve as major organizers of camps, competitions, and conferences locally and nationally for participants and coaches.

While the majority of injuries sustained in the practice of cheerleading are classified as minor and include sprains, strains, and contusions, injuries such as cervical spine fractures, injury to abdominal organs, and concussions have been reported with increasing frequency. Catastrophic injuries, including severe closed head injuries, spinal cord trauma, and death, have been found to be associated most closely with skills such as flying and tossing.

Participation in any sport or activity carries with it an inherent risk for injury; cheerleading is no different. Participants, coaches, and parents must use common sense both in practice and in competition. While no formal regulations exist at the present, it is only a matter of time before the growth of the activity necessitates more stringent guidelines for both the trainers and the trainees.

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See also Anatomy and Sports Medicine; Back Injuries, Surgery for; Concussion; Dance Injuries and Dance Medicine; Gymnastics, Injuries in; Head Injuries; Knee Injuries

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National Center for Catastrophic Sports Injury Research: http://www.unc.edu/depts/nccsi/index.htm

National Cheer Safety Foundation: http://www.nationalcheersafety.com

National Cheerleaders Association: http://www.nationalspirit.com

Chest and Chest Wall Injuries

Chest pain can be a common complaint in athletes. It is usually the result of musculoskeletal injuries. However, it is important to keep in mind other causes of chest pain. For instance, in older athletes, chest pain may result from a heart attack or other cardiac (heart) causes. The widely publicized deaths of popular college and professional athletes over recent decades have served to demonstrate that even elite athletes can have significant cardiac disease. In the presence of associated symptoms such as shortness of breath or palpitations or when there is a family history or previous medical history of heart disease, a cardiac origin of chest pain is more likely. Chest pain can also be caused by gastroesophageal reflux (GER; heartburn), gastric ulcer, pneumonia, or cancer. In addition, chest pain may be referred from the upper back.

Traumatic chest injuries typically result from rapid deceleration or high-energy impact. These injuries occur most often in high-speed and high-energy contact and high-altitude sports, including skiing, hockey, boxing, bicycling, and football. “Extreme sports” increase the potential for high-energy impacts and serious consequences because of the lack of appropriate safety precautions and remoteness from medical facilities. Significant chest wall trauma is a medical emergency.

Overuse injuries to the chest wall can also occur during sports. For instance, rib stress fractures can occur in tennis, golf, rowing, baseball pitching, and gymnastics.

Lower chest wall trauma can result in injuries to the upper abdominal organs, such as the spleen. Conversely, abdominal impact can result in a chest injury, such as pneumothorax (air in the chest cavity outside the lungs). Therefore, it is important to look for coexisting injuries in the setting of trauma.

Epidemiology

In the younger patient population (age <35 years), cardiac causes of chest pain are uncommon, occurring in less than 6% of the cases. In this age-group, particularly among athletes, chest wall conditions such as musculoskeletal strain and costochondritis predominate. In the older patient population (age >35 years), cardiac etiologies become more prevalent. Ischemic heart disease remains the leading cause of death in the United States.

Anatomy

The chest or thoracic cavity contains the heart, lungs, and great blood vessels. Two layers of pleurae, a pain-sensitive lining, surround the lungs, which are protected by the ribs and thoracic muscles. The lungs surround a central cavity, the mediastinum, which contains the heart, proximal aorta, and vena cava and is lined by a protective tissue, the pericardium. The diaphragm divides the thoracic and abdominal cavities. The position of the diaphragm changes with breathing. During expiration, the diaphragm may be as high as the fourth anterior rib. The spleen, liver, pancreas, and bowel may therefore be injured with lower chest wall trauma.

There are 12 ribs that are anchored to the spine posteriorly. The first seven ribs are attached anteriorly to the sternum with cartilage. The 8th, 9th, and 10th ribs articulate with the cartilage above them. Ribs 11 and 12 are not fixed anteriorly and are called “floating ribs.” The 10th rib is the lowest anterior rib seen. The tip of the 12th rib is at the level of the second lumbar vertebrae. Intercostal muscles run in between the ribs. The scapula protects the posterior ribs and thoracic vertebrae.

In younger children, the bony chest wall is very flexible. As children get older, the bones of the chest wall become more rigid and are, therefore, more vulnerable to fracture. The bones of children mature to adult bones by about 8 years of age.

Evaluation of Injuries

A good starting point in evaluating chest pain in athletes is to first determine whether the pain has a traumatic or nontraumatic cause. The list of nontraumatic causes of chest pain is extensive, but certain historical clues help limit the possibilities. The list of traumatic causes of chest pain is less extensive. The vast majority of traumatic injuries to the chest and thorax are typically mild, but the clinician must be wary of which causes have the potential to be catastrophic if unrecognized or if the diagnosis and treatment are delayed.

Significant injuries to the chest are medical emergencies and may result in shock. On the field, an injured athlete should have his or her airway, breathing, and circulation assessed and supported as necessary by qualified personnel. If there is significant compromise of the airway or breathing, the athlete should be intubated by a trained physician or paramedic. Intravenous access should be established with a large-bore cannula in two separate sites, and normal saline should be infused rapidly. The athlete should then be transported by an ambulance to a trauma center.

Details of Injury

History taking in the evaluation of chest pain should include questions about location, radiation, duration, character, severity, and associated symptoms. Athletes who have sustained a chest injury may present with chest wall pain and possibly shortness of breath. The mechanism of injury is typically a direct impact. In cases of chronic injuries, the onset may be more insidious. Determining the type of sport, the position played, and details of the training regimen, including any increases in training or recent changes to training, is important to help determine the cause of the athlete's symptoms. Previous medical problems may elucidate recurrent injuries.

When there is no history of trauma, it is important to distinguish between musculoskeletal causes and heart, lung, or gastrointestinal (GI) causes of chest pain. The type and location of pain may help distinguish between different causes of chest pain. Other associated symptoms such as sweating, irregular heartbeat (palpitations), or shortness of breath may indicate a heart problem. A productive cough or chest pain associated with breathing may indicate a respiratory cause of chest pain, whereas burning retrosternal (behind the breastbone) pain and indigestion may indicate heartburn or stomach ulcer.

Physical Findings

Physical examination of the thorax should begin with an assessment of general appearance and a complete set of vital signs, including pulse oximetry. A low oximetry reading (<90%) and low blood pressure coupled with an elevated pulse and respiratory rate denote the likelihood of serious cardiopulmonary compromise. Assessment of airway, breathing, and circulation of any athlete who has sustained a chest injury should be done by qualified personnel. There may be bruising at the site of injury or possibly an obvious deformity, such as a flail chest (ribs moving with breathing). If there are severe chest injuries, the athlete may have difficulty breathing and may have an increased heart rate and decreased blood pressure. There may be decreased breath sounds on auscultation of the lungs, and there may be abnormal heart sounds. There may be localized tenderness to palpation over an injured rib, which may indicate a rib fracture or muscular injury. Because upper abdominal organs may also be injured as a result of trauma to the lower chest wall, there may be tenderness to palpation or bruising of the abdomen as well. Percussion is most useful in assessing the status of the lungs and its surrounding pleural cavity. Dullness on percussion suggests a pleural effusion or consolidated pneumonia. Hyperresonance suggests a large pneumothorax. Auscultation with a stethoscope provides crucial clues regarding the clinical status of the lungs, heart, and pericardial cavity, the specifics of which are beyond the scope of this entry.

Investigations

Investigations in the setting of a chest injury include X-rays and possibly computed tomography (CT) or magnetic resonance imaging (MRI). Plain chest X-rays may indicate bony injury, such as rib fractures, or lung injuries, such as pneumothorax. An erect chest film may show free air under the diaphragm, suggesting bowel perforation. If a heart injury is suspected, an electrocardiogram (EKG) should be performed to assess for arrhythmias. An echocardiogram (ECG) may be necessary if there is significant cardiac injury. A CT scan may be necessary to further delineate the extent of lung injury.

Types of Injury

Table 1 lists the different sports-related chest and chest wall injuries.

Table 1 Sports-Related Chest and Chest Wall Injuries

Chest Injuries	*Chest Wall Injuries*
Pneumothorax	Rib fractures
Pulmonary contusion	Rib stress fractures
Hemothorax	Rib tip syndrome
Commotio cordis	Costochondritis
Myocardial contusion	Sternal fractures
	Scapular fractures

Nontraumatic Causes of Chest Pain

Nontraumatic musculoskeletal causes of chest pain in the athlete often result from training errors and overuse. Musculoskeletal pain is frequently described as sharp and may be exacerbated by chest wall expansion, as occurs with inspiration. Palpation of the chest wall may not necessarily reproduce the pain. The most commonly encountered entity in this category is the benign condition of costochondritis.

Costochondritis is a clinical diagnosis usually made based on the history and physical examination alone. It is an inflammation of the costochondral junction (where the ribs meet the sternum) presenting as localized pain and tenderness exacerbated by respiratory and exertional efforts. As it pertains to the athlete, repetitive minor trauma or unaccustomed activity has been proposed as the most likely initiating event. Treatment includes the correction of training errors and gentle stretching of the pectoralis muscle group. An athlete diagnosed with costochondritis can typically return to play once inspiration and truncal range of motion are pain-free.

The most common GI cause of chest pain is GER, better known as heartburn. Simply put, GER is the abnormal back flow of the stomach's highly acidic digestive juices into the esophagus. The resultant symptoms vary but typically include burning central-chest pain associated with belching. Less common but significant symptoms include cough and hoarseness triggered by micro-aspiration.

Exercise-induced reflux is fairly common in patients who suffer from GER at rest, but reflux only with exercise may occur in many athletes. GER increases with the intensity of exercise and is noted to be worse with endurance activities. GER has been reported in up to 90% of fed runners during and immediately following exercise. Dehydration tends to worsen the symptoms. The specific cause of GER in endurance athletes remains unclear, but it is thought to be related to changes in blood flow and GI motor function that occur during exercise. Weight lifters also experience a significant rate of GER, presumed to be secondary to increased intra-abdominal pressure from lifting. In treating an athlete with GER, altering training methods and dietary habits alone may serve to alleviate symptoms.

Acute cardiac ischemic causes of chest pain should be suspected in an adult athlete who experiences classic symptoms in the setting of sustained aerobic exercise. Suspicion should escalate if the patient possesses multiple risk factors for ischemic heart disease, including a positive family history, hypertension, and elevated cholesterol. The situation is especially urgent if the presenting symptoms are associated with syncope. Any athlete in this situation requires a comprehensive diagnostic evaluation and treatment from a cardiologist, who will eventually determine activity limitations.

Traumatic Causes

It is important for the examining clinician to be aware of the traumatic causes of chest pain, which are potentially life threatening, in an athlete. The majority of injuries to the chest and thorax are mild and include chest wall contusion or muscle strain. The more severe injuries, including cardiac and pulmonary contusion and pneumothorax, have the potential to be catastrophic if unrecognized. Sports that possess the greatest risk for severe trauma to the chest include high-speed sports, such as skiing and cycling, and high-energy collision sports, such as football and hockey.

The severe chest wall traumatic injuries posing the greatest concern include rib fracture, sternal fracture, and sternoclavicular dislocation. With each of these entities, the importance of the injury lies not with the mechanical problem itself but with the associated potential injury to vital intrathoracic structures. Specifically, fractures to the first three ribs are often associated with severe injury to the vital nerves and blood vessels, whereas fractures to the 9th through the 12th ribs may be associated with injury to the abdominal organs. Cases of sternal (breastbone) fracture have traditionally led to a search for associated injury to the heart and great vessels. To date, sternal fractures have been found to have an associated incidence of myocardial contusion of 1% to 5%, with mortality significantly less than 1%. Though rare, sternoclavicular joint dislocation is most commonly seen in football players younger than 25 years. The clavicle is typically displaced in a posterior direction, with the resultant 30% incidence of injury frequently in the form of tracheal rupture or esophageal perforation.

Isolated pneumothorax, pulmonary contusion, and cardiac contusion can result from blunt injury to the thorax. Each may present as chest pain and shortness of breath, with no visible evidence of external trauma. The possible presence of these entities should be considered after reviewing the mechanism of injury in conjunction with presenting signs and symptoms. Each possesses significant risk for life-threatening complications potentially requiring surgical intervention and intensive care. The fracture/dislocation site must be stable and range of motion and breathing pain-free before return to play is possible. It is advisable to wear a protective flak jacket for 4 to 6 weeks postinjury.

Prevention of Injury

Some chest wall and chest injuries can be prevented by wearing sports-specific safety equipment. For instance, chest protectors and safety balls in baseball have been shown to decrease the incidence of commotio cordis (heart stops because of impact injury). An automated external defibrillator (AED) should be available at sporting venues.

General conditioning is important, particularly in the prevention of overuse injuries. Core strengthening will maximize protection in contact sports and minimize overuse injuries in noncontact sports. Ensuring proper sporting techniques can also prevent overuse injuries.

Return to Sports

Decisions regarding return to play on the field should be guided by the athlete's symptoms. Before being returned to play, an athlete should have pain resolution, normal vital signs, and no peritoneal signs. The athlete should also be able to exercise without exacerbating symptoms. Any suspicion of a significant injury should prompt transfer of the athlete to a trauma center.

Return to play following rib injuries should be made on a case-by-case basis. In general, return to play is typically possible within 4 to 8 weeks. Following a sternal fracture, an athlete can return to sports once he or she is pain-free with activity. The athlete should wear a flak jacket for protection if he or she participates in contact sports.

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See also Bruised Ribs; Costosternal Syndrome (Costochondritis); Rib Fracture and Contusions; Rib Stress Fracture; Rib Tip Syndrome

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Cholinergic Urticaria

Cholinergic urticaria is the name given to hives that are precipitated by an increase in core body temperature. This is also referred to as *generalized heat urticaria*. One of the most common triggers is exercise. This entry discusses cholinergic urticaria, its triggers, how to diagnose and test for it, and how to treat and prevent it.

Epidemiology

Cholinergic urticaria is believed to account for 5% of all cases of chronic urticaria and about 30% of all physical urticaria. About 15% of the general population will experience an episode of cholinergic urticaria at least once in a lifetime. Onset is typically in the second or third decade of life. Familial cases have been reported but are rare, with all familial cases being male with father-son transmission. There may be a slight predominance in males.

Pathogenesis

The exact mechanism is not known at this time, but it is thought to be due to an abnormal cutaneous response that is triggered by increased temperatures. This results in the release of mediators that cause the urticarial response. Studies have shown that there are elevated levels of histamine in these patients.

Triggers

The most common triggers include exercise, strong emotions, and bathing in hot water. Essentially, anything that can cause a rise in core body temperature can be a trigger, including the ingestion of spicy foods. All these factors lead to increased sweat production, which has been postulated to have some bearing on the pathogenesis of the condition.

Diagnosis and Testing

Clinical Signs and Symptoms

The classic appearance is that of numerous punctuate wheals (1–3 millimeters) surrounded by a large erythematous flare ("fried-egg" appearance). As the response progresses, the flares may coalesce to form large areas of erythema. The wheals typically begin on the trunk and neck and spread distally to involve the face and extremities. Patients will often have sensations that can include itching, burning, or tingling. Rarely, this can progress to systemic symptoms such as hypotension, angioedema, and bronchospasm.

Testing

The presence of classic lesions in the setting of a typical trigger is enough to suggest a diagnosis, but diagnostic testing can be done for confirmation. A provocation test can be performed, which involves an intradermal injection of methacholine. A positive test produces hives around the injection site. This test, however, is only positive in about 33% of patients. Another type of provocation test is to have the patient mimic the activity that caused the hives (e.g., exercising, eating a certain food) in an attempt to produce a reaction. Last, the examiner can try to raise the patient's core body temperature by having the patient partially submerged in a hot water bath at 40 °C. The appearance of urticaria confirms the diagnosis.

Treatment and Prevention

Nonpharmacologic

Identification and avoidance of known triggers is the first step in controlling cholinergic urticaria. Avoiding strenuous exercise in hot weather and bathing in hot water may also reduce the chance of having a reaction. Athletes may be forced to change their training behavior and do more activities indoors in a temperature-controlled environment, and in extreme cases, an athlete may be forced to change his or her sport to avoid having an outbreak of urticaria.

Pharmacologic

Antihistamines are the treatment of choice; and of those, hydroxyzine is the agent of choice. A low dose should be started and then gradually increased until the urticaria is controlled.

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See also Skin Disorders, Metabolic; Skin Disorders Affecting Sports Participation

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Chondromalacia Patella

Chondromalacia patella is a condition in which the cartilage on the undersurface of the knee cap becomes softened or damaged. Classically, it refers to pathologic findings at the time of surgery. It differs from patellofemoral pain syndrome in that there are pathologic changes to the undersurface cartilage of the patella. It is often called "runner's knee." Chondromalacia patella is, generally, an overuse injury found in athletes with extrinsic anatomical abnormalities of the lower extremity. It can also be caused by an acute injury to the knee, such as in patellar dislocation or a direct blow to the knee. In the older population, it usually refers to osteoarthritis in the patellofemoral joint.

Anatomy

The knee joint consists of three bones: (1) the femur, (2) the tibia, and the (3) patella (kneecap). The bottom of the patella and the ends of the femur and tibia are covered with cartilage. The cartilage is what allows the bones to glide smoothly over each other. The knee joint is often considered to have three compartments. These are referred to as the medial, lateral, and patellofemoral compartments.

In addition, the patellar tendon extends from the quadriceps muscle over the patella and inserts into the tibial tuberosity. The medial and lateral extensions of this tendon form the medial and lateral retinaculum of the patella.

Causes

Chondromalacia patella can be considered as an advanced form of *patellofemoral pain syndrome.* With continued abnormal tracking of the patella over the femur, which is the cause of patellofemoral pain syndrome, the cartilage eventually begins to soften and then breaks down. The cartilage is often described as being fissured, fibrillated, or blistered. Conditions that can contribute to this abnormal tracking are femoral anteversion, external tibial torsion, genu varum or genu valgum, foot pronation, patella alta, increased Q angle (the angle measuring the relation of the femur and patella to the patella and tibia), and imbalance of the quadriceps muscles. A traumatic injury to the knee, such as a direct blow to the kneecap or recurrent subluxation/dislocation of the patella, can also cause chondromalacia patella.

Symptoms

The symptoms of chondromalacia patella often come on gradually. They are very similar to those of patellofemoral pain syndrome. Patients often complain of pain on the front of their knee that worsens after prolonged sitting, such as a long car drive or sitting in a theater. The constellation of these symptoms is often referred to as the "theater sign." Other symptoms that patients will complain of are a grinding sensation, pain with walking up or down stairs, or pain when going from sitting to standing. With prolonged sitting not only will they complain of knee pain but they will also describe a feeling of stiffness when they get up. It is also not uncommon for patients to present with bilateral knee pain. And last, with prolonged walking or activity, some patients may complain of knee swelling.

Diagnosis

Arthroscopy is needed to definitively make the diagnosis. Some clues, though, can be obtained from the history and physical exam as well as from imaging studies.

The symptoms described above in conjunction with the physical exam can help one diagnose chondromalacia patella. On exam, patients will usually have pain with compression and rocking of the patella. They can also be tender on the undersurface of the patella and over the medial and lateral retinaculum. Patellar tracking abnormalities can also be observed while having the patients flex and extend their knee. If the examiner places his or her hand over the kneecap during flexion and extension, he or she can oftentimes feel grinding, or crepitus.

X-rays looking particularly at the patellofemoral joint can show radiologic signs of arthritis that can suggest chondromalacia patella. For example, if joint space narrowing or osteophyte formation on the undersurface of the patella is present, it could be indicative of chondromalacia patella. Magnetic resonance imaging (MRI) can also show signs of fraying and cracking of the cartilage on the undersurface of the patella. Once the chondromalacia reaches Stage III to Stage IV, an MRI scan can reliably diagnose chondromalacia patella 89% of the time. Definitively, as stated above, the diagnosis is made at the time of surgery.

Once the diagnosis is made, it can typically be staged at that time. Stage I is present if there is swelling and softening of the cartilage. Stage II will have fissuring as well as softened areas. Stage III is when the fissuring extends just short of the subchondral bone, and Stage IV is when the cartilage is destroyed down to the subchondral bone.

Treatment

The approach to the management of chondromalacia patella almost always begins with nonoperative treatment. Surgery is reserved for those patients who continue to have symptoms despite maximal nonoperative management. Some newer treatments have shown benefit in providing relief for this disorder, but the mainstay of treatment continues to be conservative.

Nonsurgical Treatment

The conservative approach to chondromalacia patella focuses on physical therapy and activity modification. Simple measures such as icing, nonsteroidal anti-inflammatory drugs (NSAIDs), and reducing or modifying the activity that aggravates the symptoms can be instituted early in treatment. Next is to have the patient start with a good physical therapy program. The physical therapy program should focus on strengthening and balancing the quadriceps muscle. Often patients with chondromalacia patella have an underdeveloped vastus medialis oblique (VMO) that needs to be built up. In addition, stretching of the quadriceps, hamstrings, and iliotibial band can be helpful. Other modalities that can be employed by physical therapy include patellofemoral joint mobilization and patellar taping.

Bracing is often used by physicians for this disorder. Most of the studies on bracing have been for those with patellofemoral pain syndrome. The most common brace used is a patellar knee sleeve with passive patellar restraints plus or minus a patellar cutout. These have not been shown to reduce symptoms. Another type of brace is a patellar brace with rigid patellar restraints. This type of brace has been shown to be beneficial only if the patient is not compliant with physical therapy. For those with anatomic abnormalities, such as pes planus, orthotics can be considered.

Other nonsurgical options that can be instituted are injection therapies. There is not much evidence that supports these, but commonly, physicians will use a corticosteroid injection in the management of chondromalacia patella. In addition, viscosupplementation has been gaining popularity in the management of patellofemoral pain syndrome and chondromalacia patella.

Surgical Treatment

Surgery is saved for those who have persistent pain or dysfunction despite conservative management. It has been decreasing in popularity due to the success of conservative treatment. Arthroscopic surgery generally involves the surgeon smoothing out the irregular surface of the patellar cartilage. Any loose pieces or debris in the joint are then washed out. Some surgeons also then perform microfracture (tiny holes drilled into bone) to the undersurface of the patella for chondral defects. For those with excess lateral tilt or pressure, release of the lateral retinaculum is often performed. Distal patellar realignment procedures are sometimes done if there are patellar tracking abnormalities.

Prognosis

Most patients who are compliant with conservative treatment do well as long as the chondromalacia is not too advanced. For those who fail conservative treatment, surgery is successful in 60% to 90% of cases.

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See also Bowlegs (Genu Varum); Knee Injuries; Knock-Knees (Genu Valgum); Musculoskeletal Tests, Knee; Overpronating Foot; Patellar Dislocation; Patellofemoral Pain Syndrome; Q Angle

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Circadian Rhythms and Exercise

Circadian rhythms are self-sustaining phenomena with a periodicity of approximately 24 hours (Latin: *circa* = about, *diem* = 1 day). For example, the human circadian rhythm of body temperature shows a cosine wave pattern, typically peaking in the early evening (5–7 p.m.) and reaching a nadir in the early morning (4–6 a.m.). This entry will review evidence that exercise can influence the circadian system and discuss implications for health and performance.

Every living organism displays circadian rhythms, which probably evolved to allow adaptation to the 24-hour rotation of the earth. The bilaterally coupled suprachiasmatic nuclei (SCN) of the hypothalamus are the predominant anatomic locus of the mammalian circadian pacemaker. Neural and humoral outputs from the SCN to other centers in the hypothalamus and endocrine system drive multiple behavioral and physiological rhythms.

In humans, direct measurement of SCN activity is essentially impossible, so measurement of the human circadian system involves assessment of the output markers, such as body temperature and melatonin excretion, which can be considered the "hands of the clock." The measurement of these rhythms can be partly confounded or "masked" by environmental and behavioral factors, such as energy intake, activity, temperature, and light. For example, the diurnal rhythm of body temperature observed under normal conditions is influenced partly by day-night fluctuations in physical activity and food intake.

However, by definition, these rhythms are endogenously produced, though their measurement is influenced by these masking factors. That is, the rhythms persist even when an organism is separated from time-of-day cues or from diurnal fluctuations in these masking factors. The earliest human studies demonstrated this point in cave experiments, where there was no fluctuation in temperature and light and participants were isolated from the environment. Modern laboratory techniques have been developed to "unmask" circadian rhythms from masking factors. These include the constant routine, forced desynchrony, and ultrashort sleep-wake cycle. In the 180-minute ultrashort sleep-wake schedule, participants are allowed 60 minutes for sleep in darkness (<1 lux), followed by 120 minutes of out-of-bed wakefulness in dim light (30 lux). This schedule is repeated round the clock for up to 10 days and distributes masking effects equally around the 24-hour day.

Circadian Malsynchronization

Under ideal conditions, the circadian system is synchronized precisely to the 24-hour rotation of the earth to promote adaptation to the environment. Synchronization occurs through exposure to daily time cues (*zeitgeber*s), including the light-dark cycle of day and night, physical activity, and ambient temperature. However, when circadian timing is out of synchrony with environmental demands, there are negative consequences, as reviewed below.

Shift Work

Shift workers, who constitute about one fourth of the U.S. work force, suffer an increased prevalence of cancer; cardiovascular, endocrine, mood, and gastrointestinal (GI) morbidity; and chronic sleep impairment. Moreover, the rate of automobile and work-related accidents increases precipitously at night, as exemplified by some notorious catastrophes, such as what occurred at Chernobyl, former USSR, and Bhopal, India. Shift workers suffer these symptoms chronically because their body clocks almost never fully adjust, for example, to the graveyard shift. This is because environmental zeitgebers tend to keep humans on a diurnal schedule and because shift workers usually revert to diurnal schedules when not working.

Jet Lag

Annually, more than 50 million U.S. travelers suffer from symptoms of jet lag, including mood disturbance, sleepiness during the day, insomnia at night, and GI disturbance. These symptoms persist until the circadian system is resynchronized to the new time zone; on average, this takes about 1 day per time zone crossed. Contributing to the feeling of jet lag is "internal desynchronization" between various physiological rhythms, which occurs as the rhythms resynchronize to the new schedule at different rates. Chronic air travel in airline crews has been associated with cardiovascular disease, cognitive deficits, and menstrual cycle dysfunction. In animals, chronic exposure to simulated jet lag increases mortality and cancer progression.

Delayed Sleep Phase

Delayed sleep phase (DSP) is characterized by inability to go to sleep at a normal time (before 2 a.m.) and extreme difficulty waking up before 10 a.m. These sleep patterns correspond with delays in multiple circadian markers, including body temperature and melatonin. DSP has a clear genetic link and is most prevalent in adolescents and young adults. If given the opportunity on weekends, or through special arrangements of work schedules, individuals with DSP will often sleep until 10 a.m. to 1 p.m. and will have normal sleep quantity and quality. However, most people with DSP go to bed late and must wake up at a normal time, resulting in chronic sleep deprivation and all its consequences.

Advanced Sleep Phase (ASP)

Advanced sleep phase (ASP) is characterized by sleep onset times (~6–9 p.m.) and wake times (~2–5 a.m.) that are ≥3 hours earlier than societal norms, as well as phase advances in other circadian markers. The prevalence of ASP increases with age. A genetic link with ASP has been well documented. Excessive late-afternoon sleepiness is common in ASP, and could contribute to decreased work productivity and increased risk for accidents. Adherences to very early bedtimes can lead to some strain in social relations, and many individuals with ASP would prefer to stay up later. Moreover, extremely early morning awakening is often a source of frustration and loneliness.

Synchronizing and Phase Shifting the Circadian System

There is growing evidence that robustness of circadian rhythms (e.g., amplitude, goodness of fit) and day-to-day stability in timing are associated with better health. Indeed, greater rhythm amplitude and stability has been associated with longevity in cancer patients, Alzheimer patients, and a large sample of older adults.

Considering the prevalence and consequences of circadian malsynchronization, shifting and resynchronizing the circadian system could have tremendous potential for reducing population morbidity.

Phase-Shifting Effects of Bright Light

Bright light is considered the most important zeitgeber, shifting circadian timing via a direct retinohypothalamic pathway to the SCN. The phase-shifting effects of light (and other zeitgebers) are characterized by phase-response curves (PRCs) describing the magnitude and direction of shift, depending on the circadian time of the zeitgeber. Bright light elicits delays when administered before the circadian temperature nadir and advances when administered thereafter, with smaller effects near the temperature peak. Thus, evening light can be used to correct advanced sleep phase and to resynchronize the circadian system following westward travel. Conversely, morning light can be used to correct delayed sleep phase and to adjust to eastward travel. Perhaps just as important as receiving bright light at appropriate times is to avoid bright light exposure at times in which light shifts the circadian system in a direction opposite to that desired. For example, graveyard shift workers desiring to delay their body clocks to match their work schedule are advised to avoid bright light (if possible) when they leave for work in the morning.

Although bright light is generally helpful, it is not effective for many (but not all) blind individuals, and it is not recommended for individuals with abnormally high sensitivity to light. Moreover, field studies demonstrate that bright light has less efficacy for shifting the circadian system than might be predicted from laboratory studies. Therefore, there is a need to explore alternative or adjuvant methods for shifting circadian timing.

Phase-Shifting Effects of Exercise

Rodent and human studies have established that physical activity can also have a significant circadian phase-shifting effect. Although it is generally assumed that the phase-shifting effect of exercise is far less potent than that associated with bright light, there is little empirical evidence supporting this assumption. In our human PRC study (n = 224), we found that 1 hour of vigorous exercise (65–75% heart rate reserve) elicited a PRC that was similar in shape but with an amplitude that was approximately one-third of the PRC associated with 3 hours of bright light (3,000 lux). This difference was comparable with the difference reported by comparing phase-shifting effects of 1 hour versus 3 hours of bright light. Moreover, other investigators found approximately equivalent phase-shifting effects of 2.5 hours of moderate exercise (average intensity 50% max) versus 3 hours of bright light (5,000 lux). Finally, our more recent within-subject counterbalanced study found that exercise (1 hour at 65–75% heart rate reserve) elicited a circadian phase shift that was approximately 80% of that observed following bright light (5,000 lux) of the same duration.

In a simulated shift work study, exercise elicited a significantly greater phase resynchronization than a sedentary control treatment. Phase shift was significantly correlated with a reduction in symptoms.

Phase-Shifting Interaction of Bright Light and Exercise

In hamsters, a fascinating interaction between the phase-shifting effects of light and physical activity has been established. Light and exercise antagonize each other's phase-shifting effects when administered within a few hours of each other, but they can have additive or synergistic effects when separated by more than 4 hours. Our recent human study also found additive phase-shifting effects produced by combining bright light with exercise. Furthermore, demonstration of this interaction in humans might have great practical utility for quickly re-entraining the circadian system.

In summary, circadian malsynchronization is a highly prevalent condition associated with multiple morbidities and possibly with mortality. Although bright light provides the best means of correcting circadian abnormalities, exercise also has a significant effect on the circadian system. Moreover, both animal and human studies suggest that the stimuli can have additive effects.

Circadian Rhythms, Jet Lag, and Athletic Performance

For many years, it has been assumed that there must be a circadian rhythm in athletic performance. Certainly, circadian rhythms have been established for numerous biological and behavioral functions that could influence athletic performance, including pulmonary function, body temperature, mood, reaction time, alertness, and cognitive function.

It has often been assumed that athletic performance is optimal in the evening, when body temperature peaks. Support for this idea stems in part from the observation that many world records have been set in the evening. However, this could be explained by more favorable weather or by the fact that major athletic events are scheduled more often in the evening than in the morning.

Numerous studies of time-of-day variations in athletic performance have found that optimal performance occurs in the evening for many types of performance (particularly those lasting <2 minutes). However, this pattern might be attributed to a number of environmental and behavioral factors independent of circadian regulation. For example, worse performance in the morning versus evening could be attributed to glycogen depletion following a 12- to 16-hour nighttime fast, joint stiffness following bed rest, sleep inertia (feeling groggy) on awakening, lower ambient temperature, less muscle "warm-up" associated with daily activity, expectancy, and the fact that many athletes are less accustomed to exercising in the morning versus evening. Other flaws of previous studies on this topic are that they have generally involved small numbers of unskilled performers completing novel experimental tasks of dubious generalizability to athletic competition (such as grip strength).

A recent study by Christopher Kline and colleagues in 2007 addressed these shortcomings. Twenty-five collegiate swimmers followed a 180-minute ultrashort sleep-wake cycle (1 hour sleep and 2 hours wake) for 50 to 55 hours. In this schedule, energy intake, light exposure, and sleep were equally distributed across the 24-hour day. Each swimmer swam six maximal-effort 200-meter (m) freestyle trials at times spread across the 24-hour cycle (a total of 150 trials). A clear circadian pattern was found. Performance peaked 5 to 7 hours before the body temperature peak (~11 p.m.) and was worse from 1 hour before to 1 hour after the body temperature nadir (~5 a.m.). Circadian range from peak to worst performance was 5.8 seconds.

The study by Kline and colleagues provides the first definitive demonstration of a circadian rhythm in athletic performance, independent of environmental and behavioral masking factors. The results could have considerable importance in athletic competition. For example, among women competing in the 200-m freestyle final at the 2008 Olympics in Beijing, the first and eighth places were separated by only 1.03 seconds.

Considering evidence that body cooling promotes endurance performance, it seems plausible that endurance performance might be optimal when performed near the temperature nadir in the early morning. This hypothesis should be tested with similar methods. Conceivably, athletes could shift their body clocks so that the peak of their performance rhythms coincides with the time of competition.

The results obtained by Kline and colleagues could be particularly relevant to performance after rapid transmeridian travel, depending on the time of day of competition, the direction traveled and number of time zones crossed, and the amount of time available before competition.

For the sake of illustration, we can consider the U.S. swimmers competing in the Olympic 200-m freestyle competition. It is standard practice for athletes to travel to the Olympics at least a week before the start of the games. For previous Olympics, in which the 200-m freestyle was scheduled in the evening (local time), such a practice seemed well justified from a chronobiological perspective. The swimmer would want sufficient time to allow his or her performance rhythm to shift such that the peak of this rhythm coincides with the time of competition.

However, an interesting situation occurred in the 2008 Beijing Olympics, in which the swimming events were scheduled in the morning (local time) to accommodate U.S. evening television programming. For the Beijing Olympics, U.S. swimmers might have performed even better had they arrived in Beijing immediately before the competition, exploiting the fact that their circadian peak in performance (evening in the United States) on arrival would have coincided with the time of competition.

There could be other advantages to arriving closer to the day of competition, including avoidance of a stressful environment, more freedom to train when desired, and less exposure to viruses. It is noteworthy that many horse trainers have concluded that horses perform best when they perform immediately after transmeridian travel as opposed to waiting for several days. This result makes some intuitive sense because the symptoms of jet lag are at the highest levels during the first few days in which an organism is adjusting to a new time zone.

Nonetheless, it is generally assumed that athletic performance is impaired following transmeridian travel. This impairment could be attributed to many aspects of jet lag, including mood disturbance, sleep loss, impaired reaction time and alertness, and alteration of the normal internal milieu between various biological rhythms.

Although anecdotally, some athletes report impaired performance after air travel, critical reviews of this topic have concluded that there is no consistent or compelling scientific evidence to show that either air travel across multiple time zones or jet lag symptoms cause a reduction in sports performance. Elite athletes who have honed their skills by performing tens of thousands of practice trials over years of training might rely especially on their ability to perform, and they might be resistant to the potential effects of jet lag. The limitations in this literature that prevent defensible scientific conclusions include assessment of nonathletes performing novel tasks of dubious generalizability to athletic competitions, lack of control groups, and failure to document performance preflight.

In summary, it is widely believed that jet lag adversely influences sport performance. Jet lag symptoms are unpleasant, and it is plausible that they could cause a reduction in performance. A circadian rhythm in performance could potentially result in either improvement or impairment of performance after travel. There is a need for methodologically sound research documenting whether athletic performance is influenced by rapid transmeridian travel.

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Authors' Note: Preparation of this entry was supported by HL71560, and a VA (VISN-7) Career Development Award.

See also Sleep and Exercise; Sleep Loss, Effects on Athletic Performance; Travel Medicine and the International Athlete

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Circuit Training

Circuit training is classified as a style of exercise that benefits muscular strength, muscular endurance, cardiovascular endurance, total body flexibility, and stability if necessary. This entry discusses what constitutes a circuit training program, the variables in circuit training, and why it is important to use circuit training in a periodized training regime.

Circuit training was devised in 1959 at Leeds University in England by Morgan and Adamson as a way to improve overall fitness. Since then, circuit training has been used by athletes in all sports at some point in their training. Circuit training routines are composed of a multitude of exercises from resistance training to cardiovascular exercise, and it may use a variety of tools, including medicine balls and Kettlebells, body weight, and resistance training machines.

Program Design

The program design of circuit training will significantly alter the performance outcome. The major variables of the program design are exercise type, the amount of rest between exercises, and the number of exercises in each circuit.

Exercise Type

In determining the type of exercises for the circuit training program, it is important to factor in the individual's level of fitness, existing injuries, and current phase of training. With novice exercisers, the program is usually designed with very basic exercises. Using a resistance training machine is often the exercise of choice with novice exercisers because of the ease of use of a single plane of motion. However, the use of body weight and multiplanar exercises are also excellent and necessary for the novice exerciser, primarily to increase proprioception and functional strength for daily activities.

Many fitness centers have resistance training machines set up in a circuit as a feature for people who are new to fitness centers. The circuits alternate between upper body and lower body exercises, allowing for one part of the body to recover while the other performs. A well-known example of this type of fitness center is Curves™, a women's-only fitness center. Although an excellent concept for novice exercisers and women who may be intimidated by the coed fitness centers, extended training with the same circuits or programs will not produce the same positive adaptations from training as it did in the first 6 to 8 weeks. As per the principle of Specific Adaptations to Imposed Demands (the SAID principle), it is prudent to subtly modify the circuit's exercise structure at least every 8 weeks. Modifications can be made by changing the intensity, volume, and tempo and, more important, the plane of motion of movement and demand for stability and application to an athlete or individual's weakest link. An individual's

Table 1 Sample Circuit Training Program for a Novice Exerciser/Athlete

No.	*Exercise*	*Sets*	*Repetitions*	*Intensity*	*Rest*
1	Push-up	2–3	12–15	30–50% of 1 RM	90 seconds[a]
2	Body weight squat	2–3	12–15	30–50% of 1 RM	90 seconds
3	Seated row machine	2–3	12–15	30–50% of 1 RM	90 seconds
4	Split squat	2–3	12–15	30–50% of 1 RM	90 seconds
5	Overhead press	2–3	12–15	30–50% of 1 RM	90 seconds
6	Leg press	2–3	12–15	30–50% of 1 RM	90 seconds
7	Cable upright row	2–3	12–15	30–50% of 1 RM	90 seconds
8	Seated leg curl	2–3	12–15	30–50% of 1 RM	90 seconds
9	Biceps curl	2–3	12–15	30–50% of 1 RM	90 seconds
10	Triceps extension	2–3	12–15	30–50% of 1 RM	90 seconds
11	Plank	2–3	30-second hold	30–50% of 1 RM	90 seconds
12	Floor bridge	2–3	30-second hold	30–50% of 1 RM	2 minutes[b]

Notes: RM = repetition maximum. a. Rest prior to executing the next exercise. b. Rest prior to repeating the circuit.

Table 2 Sample Circuit Training Program for an Experienced Exerciser/Athlete

No.	*Exercise*	*Sets*	*Repetitions*	*Intensity*	*Rest*
1	Barbell front squat	3–5	12–15	40–60% of 1 RM	60 seconds[a]
2	Body weight pull–ups	3–5	12–15	40–60% of 1 RM	60 seconds
3	Single leg dead lift	3–5	12–15	40–60% of 1 RM	60 seconds
4	Physio ball DB chest press	3–5	12–15	40–60% of 1 RM	60 seconds
5	DB walking lunge	3–5	12–15	40–60% of 1 RM	60 seconds
6	Barbell bent over row	3–5	12–15	40–60% of 1 RM	60 seconds
7	Barbell step-up	3–5	12–15	40–60% of 1 RM	60 seconds
8	DB overhead press	3–5	12–15	40–60% of 1 RM	2 minutes[b]

Notes: RM = repetition maximum; DB = dumbbell. a. Rest prior to executing the next exercise. b. Rest prior to repeating the circuit.

functional weakest link is not his or her mobility or stability, rather it is his or her strength or cardiovascular endurance. Exercises in circuits providing improvement in functional mobility or stability for an individual are paramount in circuit training program design.

Rest Intervals

The durations of rest between circuit exercises and rest between repetitions of the entire circuit drastically change the ratios of the energy system's utilization. The three major energy systems used during exercise are the (1) phosphagen system, (2) glycolytic system, and (3) oxidative system. Depending primarily on the intensity of exercise, then secondarily on the duration of exercise and the rest between bouts of exercise in a circuit, one of the three aforementioned systems will be used more than the others. For example, if the work-to-rest ratios between exercises within a circuit is 4:1 (60 seconds of work and 15 seconds of rest), the primary energy system would be the glycolytic system (fast glycolysis and oxidative), which automatically becomes the primary energy system for any exercise lasting more than 10 seconds and less than 3 minutes.

When the intensity of a circuit is high to moderate (75–90% of maximum effort) and lasts less than 5 minutes, the system most stressed is the glycolytic system. However, if the circuit is of low to moderate intensity (30% or less of maximum effort) and lasts longer than 5 minutes, with little or no rest between exercises, the primary system stressed is the oxidative system. If the goal of a training phase is to increase the absolute maximal power, circuit training will not optimize power adaptations. However, improvements in functional power are seen per the need of an individual.

Number of Exercises

Circuit training traditionally involves 5 to 15 exercises in succession. Depending on the training needs and experience of the person performing the circuit, the number of exercises will vary. For a novice exerciser or beginner athlete, it is important to activate as many muscles as possible; therefore, the circuit should have more exercises—9 to 12 exercises are recommended. The duration of the training program should be at least 8 weeks but may last as long as 12 weeks, with subtle modifications to maintain consistent positive adaptations.

In the case of experienced athletes and exercisers, the number of exercises in the circuit can be fewer than nine, since the intensity and difficulty of the exercises will likely be greater than in the training program of a novice exerciser.

Tables 1 and 2 are examples of circuits for novice and experienced athletes or exercisers, respectively.

Conclusion

Circuit training is an excellent way to introduce the novice exerciser to a multitude of different exercises, as well as to allow the body to adapt to the stress of resistance and functional training. Experienced athletes and exercisers benefit greatly from circuit training as a foundational phase of their periodized training program. Muscular strength, hypertrophy, endurance, and power can all be improved with circuit training but will not reach peak levels with this form of training alone. For novice exercisers, it is perhaps the best form of training for their lifestyle and time constraints, and for the experienced athletes and exercisers, it is a fun and challenging way to transition out of the monotony of their regular training regimen.

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See also Core Strength; Exercise Physiology; Exercise Prescription; Resistance Training

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Clavicle (Collarbone) Fracture

Clavicle fractures are common injuries, accounting for nearly 5% of all fractures seen by a doctor. The injuries are more common in young athletes, with over half of them occurring in children under 7 years of age. In the pediatric population, the fractures tend to heal quite well. In adult patients, a greater force is required to break the collarbone, and they do not heal as well or as quickly.

Anatomy

The *clavicle* is the S-shaped bone between the shoulder girdle and the trunk. It helps protect the subclavian blood vessels, the top of the lungs, and the brachial plexus (nerves). The medial end is the sternoclavicular (SC) joint. This is held together very tightly by ligaments. The sternocleidomastoid muscle attaches at the superior and proximal portions of the clavicle. The distal clavicle is the acromioclavicular (AC) joint. It is stabilized by the coracoclavicular and acromioclavicular ligaments. The middle portion is the thinnest and has no ligaments that help with stability, so it is the most commonly fractured site.

Causes

The three most common mechanisms for clavicle fracture are falling onto an outstretched hand, falling onto the shoulder, and direct trauma to the clavicle.

Clinical Evaluation

History

The patients will usually present after trauma and a consistent mechanism of injury. The pain is made worse by moving their arm, so they frequently hold their arm against their chest, as if they were wearing a sling. They may report a deformity and swelling.

It is important to ask about respiratory problems such as shortness of breath. Clavicle fractures can rarely cause a pneumothorax (puncture of the lung). It is also necessary to ask about function and sensation in the affected arm, as clavicle fractures rarely can damage the nerves and blood vessels leading to the arm.

Physical Exam

Patients will have bony tenderness over the fracture site. There is usually an obvious area of swelling and deformity at the fracture site, but this is not as common with distal clavicle fractures. They will have pain with motion of the affected arm.

It is important to assess pulse and blood supply in the affected arm to rule out vascular injury. The sensation and muscle function should also be checked to rule out nerve damage. Finally, listening to breath sounds can help rule out pneumothorax.

Diagnostic Imaging

Standard anteroposterior X-rays are usually sufficient to diagnose a clavicle fracture. The 45° cephalic tilt view can be helpful with diagnosis. Computed tomography (CT) may be needed for proximal and distal clavicle fractures, as they can be very difficult to diagnose.

Treatment

Most clavicle fractures can be treated without surgery. Eighty percent of the fractures occur in the middle third, 15% in the distal third, and 5% in the proximal third. Initial care should include evaluation to ensure that there is not a more serious injury as described earlier. Then, ice and pain medications can be used to help the athlete feel more comfortable.

Patients need to be examined by an orthopedic surgeon immediately if there is an open fracture (bone punctures the skin) or if there is neurovascular compromise. Often, fractures with multiple fragments (comminuted) can be treated without surgery.

There are adult athletes who may prefer to undergo surgery to potentially reduce their time away from sports. This is mainly because adults have a longer healing time and higher risk of nonunion.

Fractures of the Middle Third of the Clavicle

The goal of treatment is to stabilize the fracture site. This is best done with a sling or a figure-of-eight brace that restricts shoulder motion slightly. The sling or brace should be continued until there is no longer any tenderness at the fracture site. Within a few weeks, there should be a bump or callus present over the fracture site. This is the area of healing bone. In pediatric patients, this will usually remodel and disappear in time.

Any progress is usually documented by a healing callus, which can be seen on an X-ray, and a nontender fracture site with full shoulder range of motion on exam. In adults, this fracture should heal in 6 to 12 weeks. In children, it can take only 3 to 6 weeks.

However, the bone is still at high risk for refracture for 1 to 2 months following clinical healing. It is important for people to avoid jobs with significant physical exertion, sports with a high risk of falling, and contact sports during this time period after healing.

Nonunion is uncommon, and these patients should be seen by an orthopedist after 12 to 16 weeks of conservative treatment. Rarely, the bone will produce a large callus, which can compress the brachial plexus and cause ulnar or median neuropathy. These patients also should be seen by an orthopedist.

Fractures of the Distal Third of the Clavicle

These fractures are classified as Types I, II, and III. Type I fractures are the most common, and they have no ligament damage or displacement. Type II fractures can be difficult to diagnose with standard X-rays. These involve damage to the coracoclavicular ligaments and have upward displacement of the clavicle. Type III fractures are through the AC joint (intraarticular).

Patients with open fractures and neurovascular compromise need to be seen immediately by an orthopedist. Patients with Type II fractures tend to heal poorly without surgical stabilization.

Fractures of the medial third of the clavicle require treatment with immobilization followed by return to play. Fractures of the distal third may require a week or two more in the sling or brace than middle third fractures.

Fractures of the Proximal Third of the Clavicle

Patients with fractures of the proximal third of the clavicle tend to feel much more comfortable seated rather than lying down. It is also important to consider if there is any fracture of the sternum (breastbone) in athletes with these kinds of fractures.

Athletes who have posterior displacement of the clavicle need urgent surgical evaluation to prevent damage to the underlying nerves and blood vessels. Healing time and return to activity are consistent with fractures of the distal third of the clavicle.

Complications

Overall, clavicle fractures have an excellent prognosis in children and adults when they are compliant with their treatment. The most serious, but thankfully rare, complication is neurovascular compromise. This can cause damage to the subclavian, internal jugular, and axillary blood vessels. There can also be a pneumothorax.

More commonly, there is a residual bony prominence that can result in a poor cosmetic appearance but generally no functional limitations.

Hypertrophic (overgrown) callus formation can cause compression of the brachial plexus and resultant peripheral neuropathy. This can be treated by surgical reduction of the callus.

Nonunion is most common with fractures of the distal third of the clavicle but can happen with any clavicle fracture. In adults, fractures that are displaced are at increased risk for nonunion.

Arthritis can occur after clavicle fractures, most commonly Type III distal clavicle and proximal clavicle fractures.

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See also Acromioclavicular (AC) Joint, Separation of; Fractures; Sternoclavicular (SC) Joint, Separation of

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Cold Injuries and Hypothermia

Cold injury encompasses a spectrum of pathophysiology from frostbite to hypothermia. Injury is caused by the body's inability to compensate for cold exposure. Activities and sports that are most commonly associated with cold injuries are those that take place in a winter or alpine environment (e.g., mountaineering, skiing), activities that involve water exposure or immersion (e.g., swimming, kayaking, triathlons, sporting events played during rain or snow), and those that are associated with prolonged endurance (e.g., ultraendurance events, marathons).

Physiology of Temperature Regulation

Humans function optimally in a narrow temperature range. The body has numerous mechanisms for producing heat when needed. With cold exposure, preshivering muscle tone increases and can double the body's baseline heat production. Because of fatigue and glycogen depletion, heat production lasts only a few hours. Increased output from the thyroid and adrenal glands also works to increase heat production. Shivering is another of the body's strategies for increasing heat production. Shivering thermogenesis increases the basal metabolic rate by two to five times.

Body temperature is influenced by four heat loss mechanisms: (1) conduction, (2) convection, (3) evaporation, and (4) radiation. Conduction is the transfer of heat by direct contact. Since the conductivity of water is approximately 25 times that of air, the body will rapidly lose heat when immersed in water. Convection is the transfer of heat associated with air movement. This form of heat loss is increased in windy conditions. Evaporative heat loss occurs when moisture on the skin converts to gas. It also occurs during respiration. Radiation heat loss occurs when heat is lost to the environment primarily from uncovered skin.

Peripheral Cold Injury

In a cold environment, the body's highest priority is to maintain its core temperature. One of the mechanisms used by the body is vasoconstriction of the circulatory system in the extremities, minimizing heat loss. This can cause the temperature of the tissues of the extremities and face to drop below the freezing point, resulting in injury. Likelihood of cold injury is also influenced by other factors such as duration of exposure, wind, humidity, altitude, clothing, medical conditions, behavior, personal variability, and hydration status.

Nonfreezing Cold Injuries

Chilblain (Pernio)

Chilblain is a reversible injury caused by skin exposed to damp, nonfreezing temperatures. It is characterized by localized erythema, edema, and cyanosis, which is often described as painful, pruritus (itching), or burning. The symptoms usually last for several days. The treatment includes rewarming, elevation, and gentle bandaging. Topical or oral steroid use has been shown to be useful. The affected areas are more prone to reinjury.

Trench Foot

Trench foot is a direct injury to soft tissues caused by prolonged exposure to cold and wet conditions. It was seen frequently among the soldiers of World War I, who spent long periods of time in water-filled trenches. Though it has most frequently been seen in military populations, it can also occur in civilian populations.

Trench foot occurs over hours to days. Initially, there is an uncomfortable tingling of the extremities. At this point, there is no permanent damage to the tissue. If allowed to continue, symptoms progress to numbness of the limb, and there is permanent damage to the tissue. The treatment is rewarming. As the extremity is rewarmed, it goes from pale, pulseless, numb, and immobile to painful and hyperemic (red) in the first few hours. Over the next 2 to 3 days, the extremity often swells and blisters form. The numbness will continue for weeks to months. In more severe cases, tissue damage can lead to gangrene and limb loss.

Freezing Cold Injuries

Frostbite

Frostbite occurs when the tissue temperature drops to less than 0 °C (32 °F). Ice crystals form in the extracellular space and pull fluid from the surrounding cells. This causes intracellular dehydration, electrolyte derangement, and protein and enzyme destruction, finally resulting in cell death. As the frostbitten tissues are rewarmed and some blood flow returns, injuries to the vascular structures cause vasoconstriction, in turn causing tissue ischemia, dry gangrene, and necrosis.

Clinical Features. Frostbite is classified by the extent of the initial tissue damage from first degree (partial skin freezing) to fourth degree (full-thickness skin, muscle, bone freezing). First-degree frostbite is associated with a stinging or burning sensation. The skin is erythematous and edematous without blisters. Second-degree frostbite is associated with the appearance of clear, fluid-filled blisters and numbness of the affected areas. In third-degree frostbite, blood-filled (hemorrhagic) blisters form. The tissue feels like a "block of wood" and has a blue-gray discoloration. Fourth-degree frostbite is characterized by a mottled or deep red hue that progresses to a dry, black appearance and possible joint pain.

Treatment. Treatment for frostbite centers on rewarming the affected tissues. Field management involves removal of wet and constrictive clothing, elevation of the affected area, and dry sterile dressing. To avoid further injury, it is often safest to initiate active rewarming in a controlled environment. Rewarming can be associated with significant pain, limiting ambulation, which can interfere with field evacuation. Rewarming should also be avoided if there is potential for interrupted or incomplete thawing since refreezing is associated with significantly worse outcomes. Once in a controlled environment, the injured tissue is rewarmed in a bath at 40 to 42 °C (104–107.6 °F). The patient should be instructed to actively move the injured area if possible. Appropriate analgesia should be administered. Care must be taken not to overheat the rewarming bath, which can cause further injuries. Dry heat such as campfires and heaters should be avoided since they tend to desiccate the injured tissues, worsening the damage. Treatments such as rubbing the affected areas with snow and friction massage are contraindicated and are associated with increased tissue damage. Except for minor cases, all patients should be hospitalized for 24 to 48 hours.

Postthaw care involves sterile debridement of clear blisters, tetanus prophylaxis, aloe vera cream, and prophylactic antibiotics (e.g., penicillin G).

The long-term effects of frostbite, especially cases involving the deep tissue, can be significant. Permanent cold sensitivity, tingling, burning electric shock sensations, and excessive sweating are all common. Thermal perception is often altered. Frostbite that involves joints and bones often results in arthritis. Discoloration of the skin can occur. In people with immature bones, growth plates can be damaged, causing abnormal growth, especially in the fingers and the forearms. Severe frostbite often results in amputation.

Central Cold Injury: Hypothermia

Hypothermia is defined as a core body temperature of less than 35 °C (95 °F). Exposure to profound cold is not necessary to produce hypothermia. Hypothermia can occur in temperate regions and during summer. Predisposing factors that increase the risk for hypothermia in the athlete population are trauma, exhaustion, hypoglycemia, immersion, exposure to cold with inadequate protection, and dehydration.

Clinical Features

Hypothermia can be divided into three stages based on core temperature. Mild hypothermia (32–35 °C/89.6–95 °F) is the excitation phase. During this stage, shivering thermogenesis is maximal. Cold-induced diuresis causes an increase in urination. There are increases in respiratory, heart, and metabolic rates, as well as blood pressure, as the body attempts to retain and generate heat. Ataxia, dysarthria (slurred speech), and apathy begin to occur in this temperature range. The body constricts the peripheral blood vessels to prevent further heat loss, causing cold extremities and increasing the risk for frostbite.

Moderate hypothermia (30–32 °C/86–89.6 °F) is the slowing phase, in which there is a slowdown of the body's functions. Shivering ceases. The metabolic rate slows down, causing a decrease in oxygen consumption, blood pressure, and pulse. Significant electroencephalogram (EEG) and electrocardiogram (EKG) changes are seen. Confusion, poor judgment, fatigue, and incoordination occur. Dehydration is a serious risk secondary to increased urination and lack of adequate mental faculty. Cardiac dysrhythmias become more likely in this stage.

Severe hypothermia (<30 °C/<86 °F) is associated with coma, dysrhythmia progressing to cardiac arrest, and respiratory failure. Hypothermic cardiac tissue becomes extremely unstable. Life-threatening dysrhythmias can occur if the patient is not handled gently. Severe hypothermia can easily be confused with death since there can be significant slowing of the body's functions. Death cannot be presumed until after full warming has taken place, which leads to the old emergency room adage: "You're not dead until you're warm and dead."

Diagnosis

Diagnosis can be difficult since many of the early clinical features are nonspecific. Also, most commonly used clinical thermometers are not adequate since they record only up to 34.4 °C (94 °F). If oral temperature is above 35 °C (95 °F), hypothermia can be excluded. Providers must have a high index of suspicion and a low threshold for obtaining temperatures on individuals exhibiting any clinical features of hypothermia. If an individual is suspected of having hypothermia, an accurate rectal core temperature must be obtained using a low-reading thermometer.

Treatment

There are three major approaches to the treatment of hypothermia: passive rewarming, active external rewarming, and active internal rewarming. Passive rewarming involves removing the individual from the cold environment and insulating, allowing the patient to rewarm on his or her own. This is most appropriate for the treatment of mild hypothermia, though many advocate using this approach for any patient with a stable cardiovascular status with even moderate hypothermia.

Active external rewarming augments the patient's own rewarming with external heat sources such as warm-water immersion, heating blankets, and warm objects (water bottles, etc.). This approach is often effective in raising the core temperature rapidly, though caution must be used especially with warm-water immersion, which can make monitoring and resuscitation difficult. Active external rewarming can be used for all stages of hypothermia.

Active internal rewarming is performed in a hospital setting. Rewarming takes place internally with techniques that include intravenous fluids, inhalation rewarming, gastrointestinal tract lavage, bladder lavage, and extracorporeal blood warming. This approach is used only in patients with cardiovascular instability and takes place in highly monitored settings such as intensive care units.

All patients with symptomatic hypothermia should be admitted to the hospital for monitoring.

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See also Dermatology in Sports; Extreme Sports, Injuries in; Frostbite and Frost Nip; Skiing, Injuries in

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Colles Fracture

A *Colles fracture* is a common fracture to one of the bones of the forearm near the wrist. These fractures are documented in athletes of all ages. Because of high-impact forces, including falls in sports such as football, snowboarding, and gymnastics, athletes who are otherwise healthy often experience these injuries. As participation in high school and junior high school sports increases, injuries such as Colles fractures are becoming more common in younger populations. This entry outlines the definition, symptoms, diagnosis, and treatment of Colles fractures in athletes.

The fracture is named after the Irish surgeon who first described it in 1814. Since that time, several classification systems have been devised to further describe this particular fracture. The Frykman classification system, for example, characterizes fractures based on the involvement of different joints at the wrist. Although it is helpful to be aware of these classification systems, the specifics are beyond the scope of this entry.

To understand the details of fractures and their management, it is necessary to have a basic understanding of the anatomy of the fracture site. The forearm contains two bones. The radius articulates, or connects, with the thumb side of the wrist. The ulna lies parallel to the radius, away from the thumb. A *Colles fracture* refers to a fracture of the radius near the wrist. The fractured portion of the radius moves dorsally, toward the back of the hand. These fractures commonly occur within 2 centimeters (cm) of the end of the radius. A *Smith fracture* is the name given to a fracture at the same site, when the fractured piece of bone tilts volarly, or downward to the palm side of the wrist.

The fracture may be isolated to the radius without joint involvement. But it is not uncommon for it to extend to the area where the radius meets the small bones of the wrist, or the joint between the radius and the ulna. There may also be an associated fracture of the ulna as well as ligament damage. The ulnar collateral ligament, which runs from the ulna to the small bones of the wrist, may experience stretching or rupture.

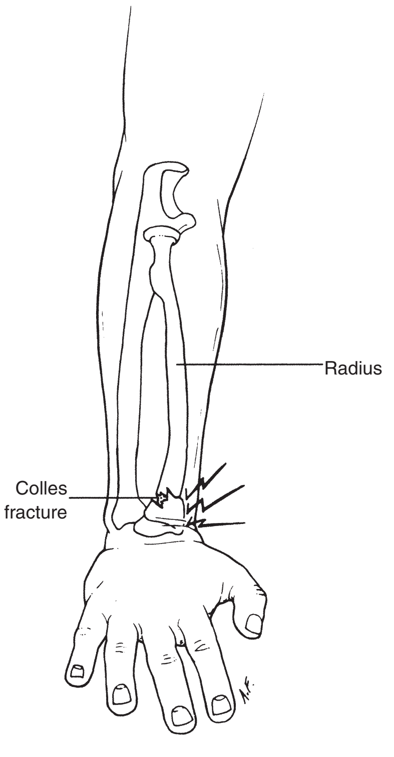

Figure 1 Colles Fracture Are Often Caused by a Fall Onto an Outstretched Arm

The appearance of the wrist following a Colles fracture is often described as an upside-down dinner fork. The fractured portion of the radius creates a bulge at the back of the wrist, similar to the curved portion of the back of a fork. The mechanism of injury accounts for the direction of the displacement of this fracture. A Colles fracture most often occurs following a fall onto an outstretched hand. This type of fall is extremely common in a variety of sports.

Snowboarding is a sport in which participants often use their hands to brace themselves when falling. Several studies have shown that the most common injury for snowboarders is one to the wrist. One Japanese study demonstrated that more experienced snowboarders were less likely to experience these fractures. Interestingly, expert snowboarders, though less likely to have fractures overall, experienced more severe fractures as a result of injuries sustained when performing jumps.

Although a fall on an outstretched hand is the most likely mechanism of injury for a Colles fracture, it is not the only one. A case report from the *British Journal of Sports Medicine* describes a unique instance of a Colles fracture. The athlete who sustained the injury was a 21-year-old weight lifter. While lifting weights at his club, he lost control and fell backward. His wrists were forced back by the weight and he landed on his elbow. The force of the weight caused a fracture to his distal radius.

Regardless of the sport involved, the signs of a Colles fracture remain the same. After the initial injury, the athlete will note pain and swelling as well as the dinner fork deformity. Bruising at the site is also common. Any motion of the wrist will increase the tenderness of the area, and the range of motion will often be compromised. In addition, athletes with this fracture will note extreme pain at the site of the injury during physical examination. It is important to evaluate the injured athlete's sensation over the wrist and hand as Colles fractures may be associated with nerve damage. Injuries may also involve arteries or ligaments, so pulses and hand motion should also be assessed.

Notably, there are fractures other than Colles fracture that present with similar symptoms. These fractures include a Smith fracture, mentioned above, as well as fractures to the smaller bones of the wrist, such as the scaphoid. Distinguishing these different entities during an on-field evaluation can be extremely difficult. To properly diagnose and treat a Colles fracture, it is essential to obtain plain X-rays of the injury. Films can demonstrate the type and severity of the fracture.

Generally, X-rays from three different views are taken to evaluate a suspected Colles fracture. These films will show the relationship of the fractured portion of bone to the rest of the radius and demonstrate the degree to which it is displaced from normal anatomy. The extent and severity of the fracture will often dictate the management; if there is any doubt as to the severity of the fracture on an X-ray, a computed tomography (CT) scan can be used for further assessment.

Treatment

The goal of treatment of a Colles fracture is to restore normal anatomy and function of the wrist. Failure to do so can compromise the athlete's motion at the wrist and thus interfere with activities such as throwing, shooting, or pushing off. Depending on the complexity of the fracture, Colles fractures may be managed by different means.

Simple fractures that are nondisplaced and do not involve the joint can be managed with immobilization alone. A double, sugar tong splint is the initial immobilization device of choice. Patients should be seen 3 to 5 days following the initial splint placement to allow resolution of the swelling before casting. At that time, the patient should be reexamined, and repeat X-rays should be taken to confirm the stability of the fracture. If the fracture remains stable, a short arm cast is applied. Follow-up X-rays as well as examinations are necessary, usually at 2-week intervals until healing is complete. These fractures generally take 6 to 8 weeks to heal.

As the fractures become more complex, however, so does the management. Displaced fractures will require manipulation of the bones back into proper alignment. Unstable fractures may require surgery to restore the radius to its normal anatomy. External or internal fixation devices can be used to anchor the fractured segments in place. Fractures that require reduction or surgical stabilization devices will require a longer period for healing.

Regardless of the method of treatment, patients should be aware of several red flags that require prompt evaluation by a physician: decreased sensation, tingling, or numbness of the fingers; discoloration of the nail beds; or worsening pain or swelling. Physical therapy is necessary after healing to strengthen the muscles of the hand and to increase its range of motion. It is important to note that return to unrestrained activities before a stable union of the fracture may result in serious complications that could compromise an athlete's ability to perform in the future. A rehabilitation program should be focused on protecting the fracture, restoring range of motion, and building strength in the affected area. A protective splint may be useful in the first month after the immobilization device has been removed.

Recognition and appropriate initial management of a Colles fracture are important for overall healing and return to play in athletes. These fractures are common injuries with the potential to impair long-term performance if treated improperly. A team approach to treatment and rehabilitation, combining the expertise of physicians, therapists, and trainers, will provide athletes with a safe, structured return to play.

Jeffrey Manning

See also Casting and Immobilization; Fractures; Snowboarding, Injuries in; Wrist Injuries

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Compartment Syndrome, Anterior

Compartment syndrome consists of a combination of pain, numbness, and/or weakness in an arm or leg due to muscle swelling or bleeding. Compartment syndrome can be an acute surgical emergency caused by broken bones or crushed limbs, but it can also occur in sports activities when the muscle grows too large because of its use during training or competition. The anterior compartment of the leg is the most common location of this syndrome. If it is not diagnosed and treated appropriately, compartment syndrome can cause loss of the ability to compete effectively as well as chronic pain, weakness, and numbness.

Anatomy

The portion of the leg between the knee and the ankle is divided into four compartments by a strong tissue called *fascia*. The anterior compartment of the leg is located just to the outside of the tibia and can easily be felt in an athlete. The muscles in the anterior compartment are responsible for bending the ankle and raising the foot away from the floor (dorsiflexion of the ankle). Dorsiflexion of the ankle is basically the opposite motion to putting pressure on the gas pedal of a car, which is called plantarflexion of the ankle. The muscles of the anterior compartment are also responsible for lifting the big toe and other toes away from the floor (extension of toes). The muscles that are contained in the anterior compartment of the leg include the tibialis anterior, which is the main dorsiflexor of the ankle; the extensor digitorum longus, the main extensor of the smaller toes; the extensor hallucis longus, the main extensor of the big toe; and the peroneus tertius. There are also nerves that pass through the anterior compartment, and the most important nerve is called the *deep peroneal nerve*. This nerve allows sensation to the space between the first two toes. There are also arteries, veins, and lymphatics in the anterior compartment. Finally, the tibia and fibula bones touch the anterior compartment and provide places for the muscles to attach.

The other three compartments of the leg are called the posterior deep, the posterior superficial, and the lateral. The gastrocnemius and soleus muscles and sural nerve are in the posterior superficial compartment. The posterior deep compartment contains the flexor hallucis longus, flexor digitorum longus, and posterior tibialis muscles and the tibial nerve. The lateral compartment contains the peroneus longus and brevis and the superficial peroneal nerve.

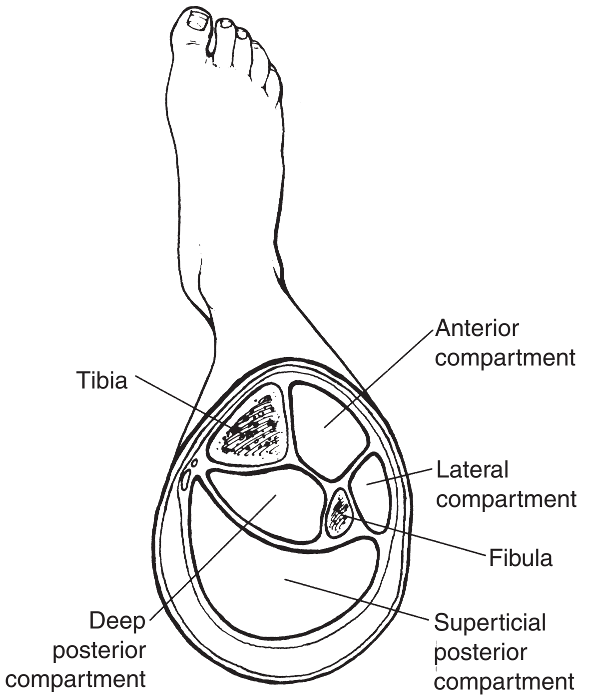

Figure 1 Anterior Compartment Syndrome

Notes: Excessive training can cause the muscles in the lower leg to grow too large for their surrounding heavy membranous walls, or compartments. At rest there is no problem, but during exercise, the muscles swell with blood, increasing pressure within compartment and producing the characteristic symptoms of compartment syndrome. The condition is most often seen in the anterior compartment.

Pathophysiology

The fascial bands surrounding the compartments of the leg are not elastic and do not stretch. If the muscles in a compartment become larger due to exercise, such as running, they can become too big for their compartment and start to become squeezed by the fascia. This is called exercise-induced, or chronic, or *exertional compartment syndrome*. The squeezing of the muscles is painful. The compression of the muscle allows less blood to get to the tissue, and the tissue that does not get enough blood becomes painful. The squeezing of the muscles causes the pressure of the compartment to increase, and that pressure can also squeeze the nerves and blood vessels. This squeezing can cause “pins and needles” or numbness and changes in the color of the leg due to changes in blood flow. This color change can be described as “mottling” of the leg. Mild forms of compartment syndrome allow the athlete to complete activity with various amounts of pain, but often compartment syndrome can become so painful that the athlete must stop the activity. The pain usually resolves with rest because the muscle at rest is smaller than the muscle in use; the muscle in use is full of blood to provide oxygen to the muscle cells. The smaller muscle fits better in the compartment and is not squeezed by the fascia.

Symptoms

The athlete will be asymptomatic at rest but will complain of pain during exertion. The pain usually begins at a predictable time during activity, such as a certain mileage or time of running. The pain is described as cramping or aching. The athlete may also notice something called *paresthesias*, which is the technical term for the “pins and needles” feeling when your arm or leg falls asleep. This should also resolve with rest. The athlete may notice weakness of the muscles of that compartment. Tightness or a sense of fullness of the leg is common during the symptomatic episodes.

Physical Exam

Much of the time, the athlete’s leg does not offer a clue to the diagnosis in the clinic because the leg looks normal. The abnormal findings are often only seen when the athlete is exercising. If the problem has been going on for a long time, there may be tenderness when the doctor presses on the leg, even at rest. It is helpful to note defects or holes in the fascia that can be felt through the skin. These will allow the doctor to feel whether the muscle is swollen because it can bulge or herniate through these holes.

If the athlete is symptomatic because of recent exercise, the physician may note a swollen or tight leg. The skin can become shiny if it is stretched over a swollen compartment. The physician will feel the compartment or leg and note any tenderness. Next, the physician will ask the patients to move their ankle up and down under their own power, and the physician will note any weakness compared with the other leg. Then the physician will move the ankle up and down and note any increase in pain. This is called passive stretch, and it is a sensitive test for compartment syndrome. There may be a change in the pulses of the foot, but this is rare. Finally, the doctor will test sensation and note if the athlete has any areas of decreased sensation. The deep peroneal nerve runs through the anterior compartment and supplies sensation to the first web space of the foot, also known as the space between the first two toes. The athlete may have changes in sensation in the first web space if he or she has anterior compartment syndrome.

The physician may measure the pressure inside the compartment with a special device that is attached to a needle inserted into the muscle. This procedure is done in a clinic and may be done before and after exercise so that the numbers can be compared. If the pressure in the compartment is normal at rest and does not fall enough after exercise, then the diagnosis is made. The diagnosis can also be made if the problem is so advanced that the pressure in the compartment is higher than normal even at rest.

Radiographs (X-rays) are usually normal in exercise-induced compartment syndrome. Magnetic resonance imaging (MRI) may show some muscle swelling but is most helpful for ruling out other causes of pain, such as stress fractures, tumors, and torn muscles.

Differential Diagnosis

Acute compartment syndrome is a surgical emergency, and the fascia must be released or the muscle and nerves can die. Exercise-induced compartment syndrome, on the other hand, is not a surgical emergency.

There are three other compartments in the leg, including the posterior superficial, posterior deep, and lateral. Each compartment has different physical findings. Many times, more than one compartment is involved.

Ruling out shin splints, or medial tibial stress syndrome, is sometimes difficult. Shin splints, like exercise-induced compartment syndrome, cause pain in athletes during exercise but usually not at rest. The athlete with shin splints will have pain on palpation of the medial, posterior aspect of the tibia. The bone in exercise-induced compartment syndrome is usually not painful on palpation.

Stress fractures can also cause pain in the leg and may not show up on an X-ray. An MRI scan can differentiate between shin splints and stress fractures.

Other problems that need to be considered include tears of muscles, contusions, blood clots, tumors, infections, and compression of blood vessels.

Treatment

Nonoperative

The most important part of nonoperative treatment is rest. Nonsteroidal anti-inflammatory drugs (NSAIDs), stretching, and ice may also help relieve the discomfort.

Operative

The physician may recommend surgery. Surgery consists of an incision over the anterior compartment, anterior to the fibula. The incision can be from a few centimeters (cm) to 15 cm long. After the skin is divided, the fascia is identified, and the surgeon opens the fascia carefully so that no tissue deep to the fascia is damaged. The skin is then closed with stitches, as long as the muscle is not too swollen.

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See also Lower Leg Injuries, Surgery for; Nonsteroidal Anti-Inflammatory Drugs (NSAIDs); Sports Injuries, Surgery for

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Complementary Treatment

Complementary and alternative medicine (CAM) encompasses health care provided outside the realm of conventional Western medicine (medicine as practiced by medical doctors, doctors of osteopathy, and ancillary professionals, such as registered nurses and physical and occupational therapists). As more and more complementary treatments are studied and proven effective, they are being adopted by, and thus called, conventional therapy. With increasing public awareness, elements of CAM are being absorbed into conventional medicine and into the everyday lives of people. Surveys and studies are increasingly demonstrating the frequent use of CAM therapies by athletes at varying levels of play.

Among the other names by which CAM is known are complementary medicine, alternative medicine, and integrative medicine, each with a slightly different connotation. Complementary medicine refers to health care provided outside the realm of, yet as a complement to, conventional medicine. In contrast, alternative medicine describes health care provided outside the realm of and instead of conventional medicine. Integrative medicine, as its name implies, is a combination of studied and proven complementary and conventional medicine.

Throughout the ages, CAM has developed with different methods of application and focuses, of which there are several. Whole medical systems, such as ayurveda, homeopathy, and traditional Chinese medicine (TCM), provide complete systems of medical practice. Mind-body medicine works within the mind's capacity to affect bodily function and health and includes therapies such as meditation and prayer. Cognitive behavior therapy, now considered conventional treatment, was once considered mind-body medicine. Biologically based practices, such as aromatherapy, vitamin therapy, and herbal therapy, use naturally occurring substances in health and healing. Chiropractic manipulation and massage are classified as manipulative and body-based practices, under which passive movement of one or more body parts promotes health and healing. The last general focus is energy medicine, including Reiki therapy, which uses energy fields in health and healing. This entry provides an introduction to some of the more commonly used CAM-focused therapies, their history, philosophy, and uses.

Acupuncture

Philosophy and History of Acupuncture

Part of TCM, acupuncture is used to promote health and to maintain balance of yin (cold, slow, passive principle) and yang (hot, excited principle). Acupuncture is practiced using a variety of techniques to stimulate specific points on the body and unblock the flow of energy (*qi*) along the body's meridians and, thus, achieve balance.

Practitioners and Practice of Acupuncture

Although the stimulation of specific body points can be practiced in several different ways, the most common acupuncture technique involves the use of thin, solid, stainless steel needles of varying length and gauge, placed at specific body points along the meridians. These needles may be stimulated by movement or by electrical current. The needles themselves are regulated by the Food and Drug Administration (FDA) and are required to be sterile, nontoxic, single-use only, and used by a licensed practitioner. Another commonly used method of stimulating the body is acupressure, during which the specific body points receive manual manipulation with the therapist's hands and fingers instead of with needles.

Although acupuncture practitioners can come from any of several different professional bases, most states require a license of some kind, although the requirements for attainment of that license (i.e., specific training) may vary. Although it may seem harmless, potentially dangerous side effects of acupuncture, if performed by an unskilled practitioner, include infection and punctured organs. Licensed acupuncturists are those who have studied for 3 years or more in an Oriental college of medicine. Chiropractors can practice acupuncture provided that they have received additional training in acupuncture. Physicians and dentists can also add acupuncture to their practices if they obtain additional training in acupuncture, although the length of training required varies by state from none to up to 300 hours. Physicians may also become board certified in acupuncture by the American Board of Medical Acupuncture.

Similar to other health care visits, acupuncture visits will follow a certain format. Typical acupuncture sessions include a discussion of the individual's medical history (e.g., medical conditions, menstrual cycle, eating and sleeping habits) as well as an examination of the patient's posture and mental state (e.g., tone of voice, emotional stress). Sessions can vary in length, although, once the needles are in, they usually last from 20 to 30 minutes. Though acupuncture can be used alone, sessions are often accompanied by the use of Chinese herbs. Sessions usually conclude with recommendations for certain lifestyle changes (e.g., diet, physical activity).

Uses of Acupuncture

Acupuncture has a variety of treatment uses, ranging from mental conditions and headaches to immune disorders and asthma. Acupuncture also has been found successful in treating addiction to illicit substances. With other mental health conditions, acupuncture helps decrease the length of stay in hospitals, as well as improves social interactions, mood, and sleep. Acupuncture research has also shown better control of allergic symptoms in patients using acupuncture in conjunction with herbs. Acupuncture has also found its way into the operating room. Acupuncture analgesia is one of the main methods of providing operative analgesia in Beijing and has been found to be beneficial in neurosurgery, thyroid surgery, tonsillectomies, and some open chest surgeries. Acupuncture research has also demonstrated a need for less traditional pain medications and a decrease of brain activities associated with pain on magnetic resonance imaging (MRI). Although further research is needed, some studies have demonstrated a decrease of symptoms from exercise-induced asthma when acupuncture was provided before the activity. Studies of acupuncture and acupressure have demonstrated a decrease in nausea and vomiting in patients who have undergone surgery and are undergoing chemotherapy. The relief and prevention of headaches is another of the studied benefits of acupuncture. Acupuncture has also been noted to promote fertility by improving fertility-related functions, such as an improvement in sperm number as well as improved follicular health and ovulation and increased vaginal lubrication.

Acupuncture is extensively used in the sporting arena. Athletes have found acupuncture an effective method for pain control. Acupuncture has also been used to treat musculoskeletal injuries and to improve performance and prevent injuries. In addition to appropriate training, acupuncture promotes muscle building and glycogen storage, stimulates substrate usage at the time of performance, and treats injuries or other chronic conditions that might affect performance.

Research and Future Directions for Acupuncture

As with many practices of complementary medicine, acupuncture research designs of the past have been difficult to interpret. Currently, the National Institutes of Health (NIH) is conducting several studies on acupuncture that are related to the treatment of low back pain, how acupuncture works, and meridians and *qi* flow. Along with growing research in acupuncture, practitioners believe that it will increasingly complement and integrate with conventional medicine. Currently, one third of the conventional medical schools have included acupuncture content in their curricula.

Aromatherapy

Philosophy and History of Aromatherapy

Aromatherapy is a type of herbal medicine that uses the essential oils of a plant in the promotion of health and healing. Practitioners believe that the wide-ranging pharmacologic properties of essential oils can aid in healing infection, promoting healthy bodily functions, and detoxifying the organ systems. Although aromatherapy has been used for healing since ancient times in China, Egypt, India, and Italy, the term *aromatherapy* was first used in 1937 by the French chemist Rene-Maurice Gattefosse, who used lavender oil to help heal his burned hand. Apart from its use in treating disease, aromatherapy has also been used to prevent diseases throughout the years. During the plague epidemic in Europe, incense was burned in sick rooms and common areas in an effort to prevent the spread of the disease.

Practitioners and Practice of Aromatherapy

Aromatherapy can be practiced using several methods, each with a variety of subpractices: (a) inhalation, which is particularly useful for respiratory conditions; (b) external application, especially helpful in the treatment of skin conditions; and (c) internal administration. Inhalation of essential oils can be accomplished with diffusers, in which small particles of the oil are dispersed into the air. Diffusion has been used for general mood improvement, in addition to improving respiratory conditions. Another inhalation method useful for relieving respiratory conditions, such as colds and flu, is the use of steam tents, under which patients inhale concentrated, oil-scented steam. Nose cones, which involve the use of concentrated oil drops on tissue papers, can also improve certain respiratory conditions, excluding asthma. With the instillation of essential oil drops into water, these “floral waters” can be sprayed onto the skin or into the air (e.g., as a room disinfectant).

With external application, essential oils are easily absorbed by the skin. There are several pleasant methods of applying the oils to the skin. Baths are easy, inexpensive, and available to many. They can encompass the entire body or a body part (e.g., foot baths, sitz baths). The heat of the bath promotes relaxation and oil absorption and also stimulates the skin and, under certain circumstances, energizes the body. Essential oil baths can help rid the body of toxins, if sweating occurs after the bath. Massage, another pleasurable method of applying oils to the skin, uses direct rubbing of essential oils onto the skin and can foster relaxation or stimulation depending on the oils and massage techniques used. Massage should not be applied to areas with infection or cancer. The application of compresses (hot or cold) can help calm minor complaints and decrease swelling.

Internal administration of essential oils should only be done under medical supervision. Administration can be by mouth or by suppository, using small amounts of oil mixed with a carrier, such as honey.

As the use of essential oils is amenable to home use and requires minimal education, the average individual can be a practitioner. A few adverse side effects have been reported, mostly involving allergic reactions and the excessive use of irritating oil. As implied earlier, precaution should be taken when considering ingesting any essential oils.

Uses of Aromatherapy

With its variety of application methods, the uses of aromatherapy are many. Essential oils can be used to treat bacterial and viral infections, such as the herpes simplex and zoster viruses. Skin conditions, such as acne and the effects of aging, also respond to aromatherapy. Muscle spasm, arthritis, and other musculoskeletal disorders benefit from treatment with oils. Aromatherapy has also been useful for the treatment of nervous system disorders, including anxiety, depression, and headaches. Other general home uses for aromatherapy include its use for daily hygiene, digestive cramping and nausea, bruises, insect bites, burns, low energy, and relaxation.

Research and Future Directions for Aromatherapy

Research and future directions for aromatherapy are continuously evolving. With research ongoing, some studies have looked at the effects of essential oils on brain waves. Practitioners anticipate an increase in the demand for and growth of aromatherapy in healing in the United States.

Ayurvedic Medicine

Philosophy and History of Ayurvedic Medicine

The term *ayurveda* comes from the Sanskrit words for life (*ayur*) and science (*veda*). Based on ideas from Hinduism and practiced in India for thousands of years, it describes an ancient, whole medical system designed to promote balance of the body, mind, and spirit and to achieve and maintain health and wellness. Over 2,000 years ago, the first Sanskrit texts on ayurveda discussed multiple health-related topics, including the cause of illness, its diagnosis, its treatment, surgery (not used in ayurveda at present), caring for children, lifestyle, advice for practitioners (including discussion of ethics), and philosophy. Ayurveda incorporates other CAM therapies, including yoga and herbs, within its practice. Widely practiced in India, Nepal, Pakistan, Sri Lanka, Bangladesh, and Tibet, yoga is becoming increasingly popular in the United States.

The basis of ayurveda includes two major beliefs: interconnectedness and constitution. Interconnectedness means that all things in the universe are connected. Disease occurs when an imbalance occurs between a person and the universe. Constitution (i.e., general health) and *doshas* comprise the second major ayurvedic philosophy. The three doshas, which comprise the basic characteristics that affect the constitution, each contain two of the five basic elements (space, air, fire, water, earth). The five basic elements are present in each person in varying degrees, affecting physical, emotional, and mental health. An imbalance, due to diet or lifestyle, can lead to disease and poor health.

Practice and Practitioners of Ayurvedic Medicine

A typical ayurveda session will include an evaluation of the individual's dosha by focusing on the patient's diet, lifestyle, and current health concerns, as well as a physical exam of the patient's overall appearance, skin, nails, teeth, weight, heart rate, digestive system, and elimination (evacuation of the bowels). The treatment prescribed often serves as a diagnostic method as well. If the patient improves, this suggests further treatments to improve the balance of the dosha to which the original treatment was directed.

Those who practice ayurveda include the therapist and the patient as well. Practitioners of ayurveda rely heavily on their patients, as many treatments also involve changes in the lifestyle and behavior of patients. As with other forms of CAM, there is no licensure or certification approved in the United States. Despite this lack of regulation, practitioners, who may also have a background in Western medicine, may train at an ayurvedic school in the United States or in India. Indian ayurveda training requires 5 years of study; practitioners can receive a degree (bachelor or doctoral) on completion of their courses.

Uses for Ayurvedic Medicine

Ayurvedic uses and methods relate strongly to the treatment goals. Using a variety of methodologies, such as diet and fasting, enemas, exercise, herbs, inhalations, meditation, medicinal oils, metals, minerals, and yoga, ayurveda helps eliminate impurities, reduce the symptoms of a disease, reduce worry and increase harmony, and eliminate physical and psychological problems. One caveat is a concern for toxicity if herbs, metals, and minerals are used, particularly if they are ingested.

Research and Future Directions for Ayurvedic Medicine

Although the interpretation of past studies has been difficult, due mainly to study design flaws, research in ayurveda continues. Current research focuses on the effects of botanicals on inflammation and asthma and the effects of other compounds on Parkinson disease. Practitioners are optimistic about the increased recognition of ayurveda and its use as a modern medical system.

Biofeedback

Philosophy and History of Biofeedback

Biofeedback is the process of using feedback mechanisms to gain improved control over one's body and body processes, some of which may be under more unconscious control. Its philosophy is one of self-regulation and control over one's body and life. First used in 1938 by O. Hobart Mowrer to detect urination with an alarm for bed-wetting, it was not formally studied until the 1960s' research on the altered state and electroencephalogram (EEG) patterns of yogis.

Practice and Practitioners of Biofeedback

Biofeedback sessions involve the use of electrical instruments to monitor body processes and provide immediate and understandable feedback to the individual. Usually, the participant begins with focusing on a small area or function, such as muscle control. As the individual becomes more aware of his or her body, he or she can increase the focus area to include general physical and mental health and well-being. Although someone will be providing the monitoring equipment and the initial instruction on focusing, the principally involved person in biofeedback is the individual undergoing the therapy.

Uses for Biofeedback

Biofeedback has been particularly helpful in the treatment of disorders affected by stress. These include mental health disorders, such as insomnia, anorexia, and bulimia, as well as pain disorders, including migraines and temporomandibular joint (TMJ) syndrome. Hypertension, incontinence, and asthma have also been improved with biofeedback.

Research and Future Directions for Biofeedback

Current research supports the use of biofeedback to help control many different conditions, including anxiety, hypertension, depression, and seizures. Biofeedback scientists envision a future in which biofeedback can be used to monitor the moment-to-moment levels of various chemicals (e.g., hormones) within the bloodstream.

Chiropractic Therapy

Philosophy and History of Chiropractic Therapy

The term *chiropractic* comes from the Greek words for hand (*cheir*) and action (*praxis*)—in other words, hands-on therapy. Chiropractic, a medical system centered on the body's structure (especially spine) and how it affects the body's function, was founded (in modern times) by Daniel David Palmer in 1895, who believed that realigning the spine could help improve the flow of energy in the body and promote health and healing. Chiropractic therapy operates on three basic principles: (1) the body has healing properties; (2) a relationship exists between body structure and body function; and (3) therapy improves that relationship, helping the body to heal itself. Currently, chiropractic therapy ranks among the 10 most used complementary therapies worldwide.

Practice and Practitioners of Chiropractic Therapy

An initial chiropractic visit mirrors other initial conventional and complementary medical visits. Practitioners obtain a health history and perform a medical exam, although the exam focuses mainly on the spine. Unlike many other CAM therapies, chiropractors will often obtain X-rays when necessary. The initial visit may also include preparations for an adjustment if warranted. Follow-up visits may include a variety of adjustments, designed to improve the range and quality of motion of an area and promote health, including manipulation (i.e., passively moving a joint outside its regular range of motion) and mobilization (i.e., passively moving a joint within its regular range of motion). Follow-up visits may also include additional treatment modalities, such as heat and ice, electrical stimulation, rest, rehabilitative exercises, counseling on diet and exercise and other behavior modifications, and dietary supplements.

Practitioners of chiropractic therapy must have a Doctor of Chiropractic degree from a 4-year academic program accredited by the Council of Chiropractic Education. Acceptance into such a program usually requires at least 3 years of regular undergraduate education. Some chiropractors will augment their education with a 2- to 3-year residency, training in a special field. Practitioners must also be licensed in the state in which they practice and maintain continuing education credits. Many, if not all, chiropractic services are covered by insurance, state workman's compensation, and Medicaid.

Uses of Chiropractic Therapy

Over half of the chiropractic patients use it to complement conventional medicine. Commonly used indications for chiropractic therapy include low back and neck pain and headaches. Side effects are commonly related to the type of therapy provided. Temporary headaches or body pains may follow an adjustment. Occasionally, dietary supplements may interact with other medications.

Research and Future Directions for Chiropractic Therapy

Research continues in chiropractic therapy. Ongoing studies are looking at the effects of the different therapies and the physiologic basis for them, as well as at the different diseases and conditions that are best treated with chiropractic therapies. Additional research focuses on the treatment success of specific conditions, such as back pain, neck pain, and headaches, as well as on the placebo effect of the treatment. Practitioners support the continued use of chiropractic therapy as a complement to conventional medicine.

Energy Medicine

Philosophy and History of Energy Medicine

Energy medicine is a complementary medicine involving the energy fields (i.e., vital force, life force) of the body. This energy, or life force, has been used in other long-standing forms of complementary medicine, including TCM (discussed later) and ayurveda (discussed earlier). It is also described by the Greek philosopher Pythagoras as "pneuma"; by the founder of Western medicine, Hippocrates, as "life force energy"; and in the Judeo-Christian tradition as "spirit." This energy is composed of veritable energy, which has been measured, and putative energy, which has not yet been measured. With veritable energy, mechanical vibrations and electromagnetic forces at specific, measurable frequencies and wavelengths of energy (e.g., sound, magnets, lasers) are used to treat patients. Putative energy, also known as biofields, is a more subtle form of energy that is believed to infuse the entire human body. Therapists manipulate putative energy with a variety of processes, including Reiki (discussed later) and healing touch therapy. Practitioners of energy medicine believe that disease comes from imbalances in the subtle energy field of the body.

Practice and Practitioners of Energy Medicine

There are several different methods of receiving energy therapy. Veritable energy therapies include magnet therapy, millimeter wave therapy, and sound and light therapies. Magnet therapy can be static, used for the relief of pain and to help relieve edema and ischemia. In fact, recent research has noted an effect on the microvasculature of skeletal muscle. Magnet therapy can also be pulsatile, which has been proven effective in the treatment of fracture nonunion. Inconclusive data exist for the use of pulsatile magnet therapy for multiple sclerosis, osteoarthritis, migraines, and sleep disturbances. Millimeter wave therapy, practiced in Russia and other Eastern European countries for decades, uses irradiation to treat skin conditions, cancers, and intestinal conditions. Despite ongoing research, its mechanism of action is still unknown. Sound therapy, also known as vibration or frequency therapy, posits that certain sound frequencies resonate with certain organ systems in the body. Types of sound therapy include music, wind chimes, and tuning forks and have been used to treat pain and various mood states, as well as to affect certain biochemicals (e.g., beta endorphins). Light therapy, the last of the veritable therapies, uses varying frequencies of light to treat disorders, such as seasonal affective disorder, sleep disorders, and depression. Ongoing research, supporting the use of low-level laser therapy in pain treatment and wound healing, continues.

As putative energy is less measurable, so are its methods. Acupuncture promotes the balanced flow of *qi* (i.e., energy) along meridians in the body (discussed earlier). Case studies of Qigong, another form of putative energy medicine, support its use for the treatment of blood pressure disorders and asthma. Homeopathy involves the use of dilutions of herbs to help the body's life force (i.e., energy) support health and promote and direct healing throughout the body. Few research studies of adequate quality exist for Qigong. Therapeutic touch, in which the application of the therapist's hands helps balance the patient's energy fields, has been demonstrated to be useful in the treatment of anxiety, headaches, wound healing, and pain.

Future Directions in Energy Medicine

Practitioners aspire to a change of focus from conventional, chemical medicine and treatment to energy medicine and disease prevention.

Massage Therapy

Philosophy and History of Massage Therapy

An ancient therapy, thousands of years old, massage therapy involves the manipulation of the muscles and soft tissues of the body to promote health and healing, via promotion of increased blood flow, decreased pain, and relaxation of muscles. Massage therapy first became popular in the United States in the mid-1800s; however, a significant increase in its use came in the 1970s, mainly in the athletic arena. Although still considered complementary for some conditions, massage is sometimes considered part of conventional medicine.

Practice and Practitioners

With its long history, massage therapy exists as more than 80 different therapies. Commonly used massage treatments include the Swedish massage, which uses long strokes, kneading, and friction; deep tissue massage, which uses long strokes and the fingers for deep pressure; trigger point massage, which incorporates a variety of deep strokes with a focus on muscle tightness; and shiatsu massage, which uses varying, rhythmic finger strokes to stimulate energy points in the body.

Massage sessions typically follow the same pattern as other forms of CAM. Conducted in a calm and soothing environment within an office, health club, or an individual home, a session usually begins with the practitioner taking a medical history and obtaining the patient's goals for the session, followed by a visual and light touch exam and then the massage. Although session times can range from 15 minutes to 2 hours, sessions generally last from 30 to 60 minutes.

An increasing number of U.S. states (33) require appropriate training for massage practitioners at an accredited school, as well as certification and licensure. Currently, massage practitioners can attain several different levels of training, licensure, and certification. Listed in ascending order, they include Licensed Massage Therapist (LMT), Licensed Massage Practitioner (LMP), Certified Massage Therapist (CMT), and National Certification Board for Therapeutic Massage and Bodywork (NCBTMB, NCBTM).

Uses of Massage Therapy

Massage therapy is used to improve pain and rehabilitation; to promote stress relief, relaxation, and a decrease in anxiety and depression; and to maintain general health. As with other conventional and CAM therapies, massage has its contraindications and precautions, including its use in patients with a tendency to bleed or clot, an active infection or inflammatory condition, cancer, nerve damage, or pregnancy.

Research and Future Directions for Massage Therapy

Current research on massage therapy is focused on how massage exerts its effect. Studies have proven that it not only decreases pain by taking the focus off the area of pain but also promotes muscle relaxation and decreases stress. Theory in massage research suggests that it might stimulate the parasympathetic nervous system, increasing relaxation; enhance the release of biochemicals, such as serotonin; improve soft tissue healing, such as decreased scarring and lymphatic drainage; augment sleep, which improves relaxation; and have a direct therapeutic effect from the interaction of the therapist with the patient. Future directions in massage therapy involve NIH research on the use of different types of massage on healthy people, for neck pain, and for improved quality of life in end-of-life care.

Meditation

Philosophy and History of Meditation

Meditation involves the suspension of the streaming thoughts of the mind. It is a form of mind-body medicine based on Eastern spiritual traditions.

Practice and Practitioners

Although many different methods of meditation exist, they all contain four key components. One must find a quiet place, free from distraction, and select a specific (based on the style of meditation) but comfortable posture. The third element involves the focus of one's attention, usually on a word (i.e., mantra), the breath, or an object. The last component is openness, the ability to acknowledge the thoughts and let them pass without losing focus. Mindfulness meditation has as its key component the focusing on and being aware of "the now" without being affected by it. Transcendental meditation involves use of a mantra, or repeated phrase, to help the mind avoid distraction. Meditation can be practiced alone or with the aid of an instructor and is often used within other CAM therapies, such as yoga (discussed later), Qigong, and Tai Chi.

Uses of Meditation

Meditation is often used to treat disorders affecting the psyche. Psychological disorders, such as anxiety, depression, lack of self-esteem, insomnia, and stress, especially benefit from meditation. Patients also experience less pain and are better able to deal with the symptoms of chronic diseases when meditation is part of their treatment. Meditation is not just for the infirm; it can be used for overall general health promotion and for motivation and performance enhancement in the athlete as well.

Research and Future Directions for Meditation

Although a mechanism of action of meditation has been proposed—a decrease in the stress response (i.e., sympathetic nervous system) and an increase in the resting response (i.e., parasympathetic nervous system)—the search for additional answers continues. What occurs in the body and mind during meditation? What conditions—such as heart disease, rheumatoid arthritis, and low back pain—might be treated with meditation?

Some practitioners envision the increasing future use of meditation in the treatment and prevention of disease.

Reiki Therapy

Philosophy and History of Reiki Therapy

Developed officially in Japan in the mid-1800s by Dr. Mikao Usui, Reiki therapy acquired its name from the Japanese words for universal spirit (*rei*) and life force energy (*ki;* analogous to the Chinese word *qi*). Dr. Usui not only defined the practice of Reiki therapy, he also created an organization for its teaching and dispersion. Dr. Usui defined Reiki therapy as a form of energy medicine in which the therapist affects and improves the flow of *ki* within and around the patient's body to achieve balance.

Practice and Practitioners

Reiki sessions are conducted with the patient fully clothed and either sitting or lying supine. The practitioner places his or her hands in 12 to 15 different positions immediately above or on specific body locations for a period of 2 to 5 minutes until the flow of *ki* stops. Reiki that is performed at great distances is termed *distance healing*.

As with other forms of CAM, no certification or licensure is required for Reiki therapy. Reiki practitioners are trained under a Reiki master, who has achieved the four levels of expertise in at least one school of Reiki therapy. As one state, Florida, classifies Reiki therapy as "massage," its therapists are required to be certified massage therapists.

Uses for Reiki Therapy

Reiki therapy has several common uses. In the area of mental health, Reiki therapy helps alleviate the effects of stress, promote mental well-being and clarity, and aid patients in dealing with the diagnosis of a terminal illness. It also can help ameliorate the side effects of cancer treatments and general pain and has, thus, been useful in postoperative recovery.

Research and Future Directions for Reiki Therapy

Currently, comparatively little is known about Reiki therapy. Research continues, attempting to determine how Reiki works and specific diseases for which it might be useful (fibromyalgia, improved quality of life for AIDS patients, disease progression in prostate cancer and associated anxiety, blood sugar control). As with other forms of energy medicine, Reiki practitioners hope for a change of focus from chemical medicine and treatment to energy medicine and prevention.

Traditional Chinese Medicine

Philosophy and History of TCM

TCM is a whole medical system used to promote health and to maintain the balance of *yin* (cold, slow, passive principle) and *yang* (hot, excited principle) and the flow of *qi* (energy, life force) along meridians (pathways) in the body and through the organs. The term *yin* is often used to describe organ or tissue, while *yang* is often used to describe the activity of the organ or tissue. Organs themselves are also defined according to either yin or yang, as well as according to the five phases (fire, earth, metal, water, and wood). As fire can burn wood and water can destroy fire, all of the phases and, thus, the organs, promote or inhibit the actions of another, creating synergy and harmony within the body.

TCM, practiced for more than 5,000 years, is one of the world's most widely accepted and used forms of medical health care. Practitioners aim to treat the patient and not the disease and consider prevention the key. Early discussions of lifestyle (e.g., diet, exercise, stress management and relaxation, rest) reflect their focus on preventing illness and promoting health.

Practice and Practitioners of TCM

As with many other forms of medical therapy, conventional and CAM, a typical session of TCM begins with an examination of the history of the patient's present concerns (symptoms), the patient's medical history, his or her current behavior (e.g., diet, lifestyle, sexual activity), and any previous treatments used to treat this concern. This history taking is followed by an examination of the patient's general demeanor (body language, tone of voice), pulse, body odor (e.g., sweat, breath), abdomen, and the meridians.

Over its long-standing history, TCM has evolved a variety of treatment types, including the use of herbs, diet therapy, acupuncture, massage, and energy healing.

Herbs are a common part of TCM. Coming from plants, animals, and minerals, the herbs can be taken in many forms, including as decoctions, pills, tinctures, suppositories, soaks, and poultices. Herbal therapy has been proven to strengthen specific and nonspecific immunity, as well as to relieve some of the effects of chemotherapy medications. Those who practice diet therapy believe that foods have healing properties, helping to balance *qi* that is out of sync. Ginger, for example, has been used to aid digestion and to fight infections, such as colds. Acupuncture, discussed earlier, involves the stimulation of certain points along the body's meridians to improve the flow of *qi*. Massage therapy and manipulation can balance the flow of *qi* and are often used in combination with other therapies. Energy healing therapies, including Qigong and Tai Chi, can be used for chronic medical conditions. Qigong has been used to ameliorate hypertension, respiratory disease, and cancer.

Uses of TCM

In addition to the indications for TCM listed above, TCM also may be used to treat asthma and allergic conditions; headaches; systemic diseases, such as diabetes, lupus, and infections; and organ system diseases, such as gallbladder diseases and gynecologic disorders. Athletes find the herbs used in TCM particularly useful, including Siberian ginseng, a gentle herb that affects the adrenal glands, helping the body better adapt to stresses, such as the physical stress of athletic performance; Cordyceps, a tonic use to decrease lung inflammation, which can be helpful for exercise-induced asthma; and ginseng, a herb that affects a variety of organ-system functions, with the effect of improving energy levels and maintaining alertness.

Research and Future Directions for TCM

Current research supports the use of TCM as a complement to Western medicine in acute and chronic conditions. Practitioners anticipate that TCM may begin to incorporate other aspects of medicine (e.g., electro-acupuncture, biofeedback testing, modern homeopathy) to become "integral Chinese medicine" in the future.

Yoga

Philosophy and History of Yoga

Yoga is an area of mind-body medicine that uses certain body postures, breathing, meditation, and relaxation to promote health and healing. Initially, yoga originated in India as a way to direct one's attitude and behavior and to achieve spiritual enlightenment. With the writing of *The Yoga Sutras,* the first text of yoga, 2,000 years ago, eight factors were clearly described in the promotion of physical and mental well-being: (1) moral behavior, (2) healthy habits, (3) physical postures, (4) breathing exercises, (5) sense withdrawal, (6) concentration, (7) contemplation, and (8) higher consciousness.

Practice and Practitioners of Yoga

With its ancient history, yoga has developed into a variety of different styles of practice, all of which focus on different combinations of the eight sutras. Hatha yoga, the most commonly practiced yoga in the United States, uses two of the eight sutras, physical postures and breathing exercises.

Although no definitive certification or licensure to teach yoga is required in the United States, many organizations provide formalized training and certification. The specific training required for certification depends on the style of yoga.

Uses of Yoga

Yoga has been used to treat a variety of diseases, including psychological disorders such as high stress, anxiety, and depression. It also benefits patients with heart and respiratory conditions, such as high blood pressure and asthma, respectively. Yoga can also be used for the promotion of physical fitness and overall health and well-being. As with other therapies, yoga has its contraindications as well, which include bone or disk disease of the spine, extremely high or low blood pressure, glaucoma, ear problems, severe osteoporosis, and blood clots in individuals who are at risk for such clots. Yoga can also be used to promote general musculoskeletal health, affecting posture, balance, and gait. As such, athletes can find it a useful adjunct to their overall training.

Research and Future Directions for Yoga

Research in yoga continues. Several studies support the use of yoga for the treatment of mental health conditions such as anxiety, depression, overall mood, insomnia, and stress. Additional research points toward yoga fostering better cardiorespiratory fitness, with improved lung capacity and decreased blood pressure. Musculoskeletal conditions have also been proven to benefit from yoga, resulting in improved flexibility and strength and muscle relaxation. Ongoing research on yoga's effects centers on blood pressure, chronic back pain, arthritis, immune function, and smoking cessation.

Conclusion

Although the definition of CAM encompasses health care provided outside the realm of conventional, Western medicine, better understanding and improved research are gradually making its use more mainstream. With its inclusion of whole medical systems, mind-body medicine, biologically based practices, and energy medicine, CAM focuses on the whole patient in the promotion of health, well-being, and athletic performance and in the treatment of disease and disability.

Nailah Coleman

See also Acupuncture; Bioenergetics of Exercise and Training; Biofeedback; Circadian Rhythms and Exercise; Dietary Supplements and Vitamins; Electrical Stimulation; Electrotherapy; Exercise and Disease Prevention; Future Directions in Sports Medicine; Hypnosis and Sport Performance; Imagery and Visualization; Seasonal Rhythms and Exercise; Sports Massage Therapist; Therapeutic Exercise; Vegetarianism and Exercise

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Complex Regional Pain Syndrome

Complex regional pain syndrome (CRPS) is a puzzling chronic pain syndrome with underlying dysfunction of the central and/or peripheral nervous system. Usually involving an arm or leg, CRPS causes continuous, intense pain out of proportion to the severity of injury. This uncommon disorder can affect athletes with limb injuries. This entry provides a discussion of CRPS, with an emphasis on diagnosis and treatment.

Prevalence

The prevalence of CRPS is uncertain. Both men and women are affected, and a person can develop CRPS at any age. CRPS tends to be more common in young women. Depending on how CRPS is defined, the incidence varies from common to nonexistent. Equally mysterious is the underlying cause of CRPS.

Pathophysiology

Generally, two types of CRPS have been identified. In CRPS Type I, known historically as *reflex sympathetic dystrophy,* nerve damage cannot be found. In CRPS Type II, or *causalgia,* nerve damage can be detected, but the pain mysteriously extends beyond the injured nerve. The pathophysiology of CRPS is a matter of significant debate. Pain receptors may become more responsive to nervous system messengers known as *catecholamines* after nerve damage. Another theory is that the underlying injury triggers an immune response. CRPS is quite likely multifactorial, with no single underlying cause. Research is enhancing our understanding of CRPS, but there are still many unanswered questions.

Physical Examination

CRPS is difficult to diagnose. In patients with severe, advanced CRPS, recognizable features are present, including limb pain, heightened skin sensitivity, a smooth shiny skin with abnormal skin color and temperature, joint stiffness, and diffuse swelling. However, early in the disorder, CRPS symptoms and signs may be mild. Research has revealed that no psychological or personality traits appear to predispose individuals to CRPS. Additionally, fracture type and severity of injury are not significantly different from those in patients who recover normally. Any athlete could therefore be affected by CRPS regardless of the degree of injury.

Symptoms

CRPS can cause a wide variety of symptoms. A key component of CRPS is continuous, intense pain out of proportion to the severity of injury. The pain is usually described as "burning" or "stinging." Other symptoms include increased skin sensitivity (i.e., clothing resting on the affected body part causes pain) and increased sensitivity to temperature differences (in the environment and while bathing).

Signs

Commonly observed signs include changes in skin temperature (warm or cold), color (blotchy, pale, red), and texture (shiny, sweaty) compared with the unaffected body parts. Nails become brittle, and hair stops growing. Swelling, decreased range of motion, and weakness are reported.

Stages

Some experts think that CRPS exists in three symptomatic stages and that patients progress from one stage to the next. Stage I lasts from 1 to 3 months and includes severe pain, color and temperature changes, muscle spasm, and joint stiffness. Stage II lasts from 3 to 6 months and includes increasing amounts of pain, swelling, decreased hair growth, brittle nails, stiff joints, and weakened muscles. Stage III is the final stage and is manifested by disuse of the body part due to pain, muscle loss, and joint stiffness, with resultant contractures and, occasionally, contorted limbs.

Diagnosis

Diagnostic Criteria

Diagnostic criteria for CRPS exist, although there is no consensus as to the best method of diagnosis. No one test identifies all patients with CRPS. Additionally, CRPS presents differently from one person to the next, and symptoms vary over time. The key to diagnosis is to remain alert for this disorder based on clinical symptoms and signs.

Other Disorders

When diagnosing CRPS, other disorders need to be ruled out. The differential diagnosis for limb pain in an athlete is quite broad and includes orthopedic, vascular, autoimmune, infectious, and neurologic conditions. Useful studies to include in the evaluation of an athlete with possible CRPS include laboratory tests (complete blood count, inflammatory markers), nerve conduction studies, X-ray, and possibly advanced imaging (bone scan, magnetic resonance imaging [MRI]). A multidisciplinary approach may be needed to make an accurate diagnosis.

Studies Specific for CRPS

Various laboratory tests and imaging procedures have been applied to CRPS. The majority have not been evaluated with regard to their sensitivity (i.e., the probability that a patient with CRPS will have a positive result) or specificity (i.e., the probability that a patient without CRPS will have a negative result). Diagnostic instruments have been plagued by difficulties in objective measurement of clinically apparent signs such as hand volumetry to measure swelling, thermometry to measure skin temperature, and resting sweat output to measure sweating. Unfortunately, many variables can affect these instruments, such as time of day, environmental and body temperatures, and correct placement of the device, decreasing their usefulness. Radiological studies such as X-rays and bone scans appear to add little compared with clinical assessment. Sympathetic nerve blocks have demonstrated poor sensitivity and specificity for diagnosis.

Treatment

Treatment of CRPS is largely based on expert opinion and is in need of more study. Although no clear guidelines exist at present, research has shown that a multidisciplinary approach appears to work best. The goal of treatment is functional restoration. Functional restoration includes normalizing range of motion and flexibility, minimizing swelling, and increasing functional use in activities of daily living, leisure activity, and work. For athletes, return to safe and successful play is paramount and is an added goal.

Therapy

Treatments for CRPS should include those least likely to do harm. The cornerstone of rehabilitation appears to be early physical, occupational, recreational, and vocational therapy. Slow, steady progression is critical as aggressive therapy can trigger pain, swelling, distress, and fatigue and may exacerbate inflammation and therefore symptoms of CRPS. Patients begin with very gentle range of motion of the affected limb, with a steady progression to incorporate load bearing. Additionally, normalizing sensation is critical, so that patients no longer experience pain out of proportion to normally nonpainful stimuli. This may include specific therapy with fabrics and contrast baths.

Psychologic Therapy

CRPS is a biopsychosocial disorder, and the psychological aspects of treatment are also important. Psychologic therapy focuses on educational goals such as teaching the patient that pain does not indicate tissue damage and that therapy is crucial to begin regular use of the affected body part. The negative effects of disuse are emphasized. Immobilization, disuse, and fear of movement can lead to significant phobias. Often, the fear of movement is more disabling than the pain of CRPS itself. Relaxation training with biofeedback, training in pain coping skills, and behavioral interventions that address disuse and activity avoidance are frequently used. Correction of misinformation and reframing the involvement of the patient (as an active, not passive participant in therapy) are key aspects of cognitive behavior therapy and can be helpful. Those with CRPS frequently have coexistent depression, anxiety, and posttraumatic stress disorder. These associated conditions also need to be addressed as they can heighten the pain from CRPS and make treatment more difficult.

Medical Management

If a patient is not progressing in a reasonable amount of time, other agents can be employed. Pain management is the focus of these additional treatments. A wide variety of medications can be used to treat the pain from injured nerves, skin, and muscle and include topical analgesic drugs, which act locally on the affected body part, antiseizure drugs, antidepressants, corticosteroids, and opioids. Unfortunately, no medication has proven to provide consistent results. If pain persists, interventional therapies take on a larger role and can include sympathetic nerve blocks (placing an anesthetic adjacent to a nerve), spinal cord stimulation (placing electrodes next to the spinal cord), implantable spinal medication pumps, and sympathectomy (destroying the nerve either temporarily or permanently). Multiple specialists are involved in the care of a patient with persistent symptoms.

Pediatric Patients

Pediatric patients tend to have greater lower limb involvement. The primary focus of treatment in pediatrics is similar to treatment for adults, beginning with therapy. Children tend to have a milder course, which is felt to be secondary to better participation of children in therapy. Recurrence is higher in children, but they respond well to additional treatment. Medications and invasive procedures are used cautiously in children.

Prognosis

The prognosis for patients with CRPS is variable. Some cases resolve spontaneously, while others have a severe, unremitting course. In both adults and children, athlete-specific guidelines are nonexistent. Return to play should be decided individually. Return to normal life is key as CRPS can be debilitating.

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See also Pain Management in Sports Medicine; Psychological Assessment in Sports; Psychology of the Young Athlete

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Concussion

Each year in sports, it is estimated that nearly 300,000 concussions occur at all levels of competition. Concussions are likely underreported as athletes may withhold their symptoms from coaches, teammates, parents, athletic trainers, and physicians for fear of being kept out of competition.

Definition

In 2001, a new definition of sports-related concussion was proposed. *Sports-related concussion* is defined as a complex pathophysiologic process induced by biomechanical forces that affects the brain. Major features of a sports-related concussion include the following:

- Caused by a direct blow to the face, head, neck, or other area of the body, which results in an impulsive force to the head

- Short-term impairments to neurologic function that resolve on their own
- Typically a functional rather than a structural impairment
- May or may not involve loss of consciousness
- Typically associated with normal computed tomography (CT) and magnetic resonance imaging (MRI) studies

Pathophysiology

Currently, there is no human experimental model for the pathophysiology of concussions. Animal models have suggested abnormalities of brain metabolism affecting glucose. It is unclear if this model can be applied to the human sport concussion.

Signs and Symptoms

There are many signs and symptoms that an athlete may present with after sustaining a concussion. An athlete may present with a sign or symptom in isolation or in combination. Signs and symptoms may include headache, vomiting, nausea, sensitivity to light or sound, ringing in the ears, difficulty concentrating, memory loss of events both before and after the concussion, unsteady balance, slurred speech, "glassy-eyed" staring, loss of consciousness, feeling foggy or slow, emotional changes, and visual changes such as blurry vision, "seeing stars," or double vision.

Physical Examination and Evaluation

On-Field Assessment

In the acute setting for athletes who are evaluated on the field, the initial evaluation should be for consciousness, as the unconscious athlete must be assumed to have a cervical spine injury and appropriate management must be initiated. If an athlete is conscious, assessment of his or her cognition, including details of the current game, amnesia before or after the injury, and confusion must be assessed. The athlete should be asked about the symptoms related to his or her concussion.

The physical exam should be focused on neurologic assessment, including evaluations of short-term memory and observation of balance ability, changes in personality, ability to follow instructions or answer questions, vomiting, or emotions inappropriate to the situation or the athlete, such as laughing or crying.

A useful sideline assessment tool is the Sport Concussion Assessment Tool (SCAT), which was developed during the 2004 Second International Conference on Concussion in Sport. The SCAT is a combination of various previous sideline evaluation tools, which used the most evidence-based assessments of each of these tools.

In-Office Assessment

If the first assessment is in an office-based setting, history of the concussion and any prior concussions must be obtained. A thorough neurological assessment should be undertaken, as well as evaluation of cognitive function. A postconcussion symptom checklist with grading of the common symptoms related to concussions can be useful to assess the present condition of the athlete and to follow up his or her improvement over time.

Neuroimaging

In the vast majority of sports-related concussions, results of neuroimaging studies such as CT and MRI scans are normal. Indications for considering further neuroimaging would include worsening neurological status, recurrent vomiting, focal neurologic findings on physical exam, and loss of consciousness. Further imaging may also be warranted in a person with symptoms that are not improving over a 10-day period, as most concussions will see improvement of symptoms over that time. There is no consensus as to how long an athlete should have been unconscious to require neuroimaging. Various sources suggest loss of consciousness for at least 30 to 60 seconds before one may consider further neuroimaging.

Current research is focused on functional MRI scanning as a potential neuroimaging study to evaluate concussions.

Neuropsychological Testing

The use of neuropsychological testing, both in computerized and in pencil-and-paper forms, is becoming more commonplace in the evaluation of an athlete following a concussion. It is one tool in the comprehensive evaluation of an athlete with a concussion. Current recommendations are to consider evaluating an athlete with a neuropsychological test following resolution of symptoms, as a symptomatic athlete will not be returned to play. Comparing a test's results with a previously obtained baseline for that athlete is helpful but not required.

Concussion Management

Symptomatic athletes should be rested both from physical and cognitive activities. That may mean accommodations for the athlete in school with reduced school load, prolonged times for testing, and even staying home from school. Athletes should not be returned to physical activity until their symptoms have resolved.

Return to Sports

In recent years, there has been a dramatic shift from the use of various grading scales to determine the appropriate time to return an athlete to play following a concussion to a symptom-based approach to return to play. It is currently recommended that no athlete be returned to play while still suffering from any symptoms of the concussion. No longer is it recommended that an athlete return to play the same day of his or her concussion.

Once symptoms have resolved, it is recommended that the athlete follow a stepwise return-to-play protocol over a 5-day period. If athletes do not have return of their symptoms following each step, they can progress to the next step. If they have a return of their symptoms, they should wait an additional 24 hours and repeat that same step.

The first step would include light aerobic exercise such as light jogging or easy activity on an exercise bike. The second step involves more sport-specific training, which may include running sprints or skating on the ice. The third step involves participating in noncontact training drills. The fourth step allows full contact practice after being medically cleared. In the final step, the athlete is allowed to return to game play. Each step should take a minimum of 1 day to proceed to the next step, but if there is any return of symptoms, it may take an athlete longer than the minimum 5-day plan to return to competition.

Postconcussive Syndrome

Some athletes have a more prolonged course of symptoms following a concussion. Symptoms that persist beyond 3 to 4 weeks define the postconcussive syndrome. Symptoms include recurrent headaches, impaired memory, alcohol intolerance, depression, ringing in the ears, anxiety, loss of libido, sensitivity to light, dizziness, and difficulty in concentrating and balancing. Development of postconcussive syndrome has not been demonstrated to be related to the severity of the concussion. Athletes with postconcussive syndrome may need to be treated with medication to control their symptoms and may benefit from formal neuropsychological assessment.

Second-Impact Syndrome

Second-impact syndrome is a rare condition that has been defined as an event in which diffuse cerebral swelling, and potentially death, occurs when an athlete sustains a second hit, or concussion, when not fully recovered from the first one. There has been debate as to whether this syndrome, as described, actually exists. There have been published reports in both medical journals and the lay press of athletes, typically those below age 20, who have had diffuse cerebral swelling on autopsy. The difficulty lies in determining whether these athletes had the cerebral swelling from a solitary hit or multiple hits.

Prevention

Ideally, preventive measures can be developed to continue to reduce the likelihood of concussions. These may include modifications to equipment, such as changing helmet designs, better rule enforcement or development of new rules, and education of players, coaches, officials, and families about concussions.

Mark Halstead

See also Catastrophic Injuries; Football, Injuries in; Head Injuries; Protective Equipment in Sports; Rugby Union, Injuries in

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Conditioning

Conditioning is a learning process in which an organism's behavior becomes dependent on the occurrence of a stimulus in its environment. In physiology, it is a behavioral process whereby a response becomes more frequent or more predictable in a given environment as a result of reinforcement, with reinforcement typically being a stimulus or reward for a desired response.

Conditioning for sports is a physical or psychological training that prepares the athlete for a specific sport. It is usually defined as a systemic process of repetitive, progressive exercise or work, involving the learning process and acclimatization. Through the use of systemic work increments, improved voluntary responses by the organs are attained. Through constant repetition, the conscious movements become more reflexive, requiring less concentration by the higher nerve centers, and this reduces the amount of energy expended by eliminating unnecessary movement for the performance of the desired task.

Conditioning for sports participation prepares the athlete for high-level performance and reduces the likelihood of injury. A considerable number of injury etiologies are directly attributable to insufficient or improper conditioning. Some of these causes include inadequate cardiovascular or muscular endurance; inadequate muscle, tendinous, or ligamentous strength; inflexibility; poor body composition; faulty neuromuscular coordination; and muscular imbalance. Modern sports programs often require elaborate conditioning facilities and equipment for injury prevention.

Principles of Conditioning

The following principles should be applied in all programs of training and conditioning to minimize the likelihood of injury: warm-up/cooldown, motivation, overload, consistency, progression, intensity, specificity, individuality, minimization of stress, and safety.

Warm-Up/Cooldown

The main purposes of warming up are to raise the general body and the deep muscle temperatures and to stretch collagenous tissues to permit greater flexibility. This reduces the possibility of muscle tears and ligamentous sprains and helps prevent muscle soreness. It takes at least 15 to 30 minutes of gradual warm-up to bring the body to a state of readiness. The time needed for satisfactory warm-up varies with the individual and tends to increase with age.

Cooling down is the gradual diminishing of work intensity, which permits the return of both circulation and various other body functions to pre-exercise levels. Gradual cooldown is recommended because it decreases blood and muscle lactic acid levels more rapidly than just allowing passive recovery. Cooling down also keeps the heart pump and muscle pumps active, preventing blood from pooling in the extremities. When cooling down, it is recommended to allow 30 seconds to 1 minute for jogging, followed by 5 minutes of walking to permit the body to adjust to the nonexercise mode.

Motivation

Athletes who are highly motivated tend to be very self-confident about their abilities. Thoughts that come into an athlete's mind during competition can be either positive or negative. The athlete must learn to control his or her thoughts and to structure them to his or her advantage. By varying the training program and incorporating different aspects of conditioning, the program can remain enjoyable rather than becoming routine and boring. An athlete's motivation to improve may come from within or may be the result of coaching demands.

Overload

The principle of overload states that a greater than normal stress or load on the body is required for training adaptation to take place. The body will adapt to this stimulus. Once the body has adapted, then a different stimulus is required to continue the change. For a muscle (including the heart) to increase its strength, it must be gradually stressed by working against a load greater than it is accustomed to. To increase endurance, muscles must work for a longer period of time than they are accustomed to. If this stress is removed or decreased, there will be a decrease in that particular component of fitness. Keeping a workout stimulus status quo will maintain the current fitness but not improve it.

Consistency

Conditioning for sports must be programmed on a consistent basis to be effective.

Progression

The principle of *progression* implies that there is an optimal level of overload that should be achieved and an optimal time frame for this overload to occur. Overload should not be increased too slowly or improvement is unlikely. Overload that is increased too rapidly will result in injury or muscle damage. Exercising above the target zone is counterproductive and can be dangerous.

Intensity

Intensity refers to how hard one exercises. Intensity can also describe the amount of energy needed to perform a particular exercise or activity. For cardiorespiratory training purposes, intensity is expressed as a percentage of maximal heart rate or heart rate reserve and is displayed in heart beats per minute. For resistance training, intensity usually refers to a percentage of the person's repetition maximum. For purposes of flexibility training, intensity usually refers to the degree of stretch or "stretching sensation."

Specificity

The *specificity principle* simply states that training must go from highly general training to highly specific training. The principle of specificity also implies that to become better at a particular exercise or skill, you must perform that exercise or skill. The program must be designed to address specific components of fitness relative to the sport in which the athlete is competing.

Individuality

Because every athlete is different, each person's response to exercise will vary. A proper training program should be modified to take individual differences into account. The coach or athletic trainer must recognize these individual differences and adjust the conditioning program to the individual athlete.

Minimize Stress

Coaches and athletic trainers must consider stressful aspects of the athlete's life. For example, student athletes have two extremely time-consuming jobs: school and sports. Success in either hinges on how well a student athlete handles stress and pressure on and off the field. The probability of performing consistently well in both can be greatly enhanced by learning and implementing key principles from sport psychology.

Safety

The training environment must be as safe as possible. Exercise programs are devised with the goal of improving one's health and fitness levels. Yet any training regimen can prove inherently dangerous if certain guidelines are ignored. If an individual consistently ignores some parts of the activity program and overemphasizes others, he or she risks injury. In addition, he or she jeopardizes his or her chance of achieving the desired goals. Examples of safety measures include lifting weights with a partner and cleaning of equipment between uses to prevent spread of infections.

Conditioning Seasons

Sports conditioning often falls into four seasons: (1) postseason, (2) off-season, (3) preseason, and (4) in-season.

Postseason

Conditioning during this season is commonly dedicated to physical restoration. This period is particularly appropriate when the athlete has been injured during the season. This is a time when postsurgical rehabilitation takes place and detailed medical evaluations can be obtained.

Off-Season

During this season, athletes are not required to continue an intensive conditioning program.

However, it is recommended that they participate in sports activities sufficiently demanding to require a good level of fitness to participate effectively. If it is not feasible for the athlete to participate in an off-season sport, a detraining program should be planned. This program will allow a gradual decrease in the usual workload and allows the athlete to exercise less frequently and less intensively. Usually, a weekly workout of moderate to heavy intensity is all that is required. It must be kept in mind, however, that caloric intake must be decreased accordingly when the exercise load is decreased, since not as much energy is burned.

Preseason

If the athlete kept a reasonably high level of physical fitness during the off-season, the preseason will be more rewarding, with less potential for injuries. During the preseason, flexibility, endurance, and strength should be emphasized in a carefully graded developmental program. No difficulty with reaching a state of athletic fitness suitable for competition within 6 to 8 weeks should then be experienced.

In-Season

Athletes need to undergo maintenance conditioning during the competitive season. If not, they may lose their base level of physiological fitness earned during the preseason. The sport itself is not enough to maintain this level.

Major Components of a Good Conditioning Program

Preconditioning

Preconditioning gives the body time to adjust and provides a safe, gradual response to exercise to avoid injury, rather than too much exercise too soon. It is less demanding on the cardiovascular and muscular systems. An example is the use of low-gear biking on level ground before adjusting to high-gear cycling on the hills.

Warm-Up

The two components of any warm-up program are low-intensity activity and stretching. The purpose of warm-up is to gradually increase the heart rate, reduce muscle stiffness, increase the blood flow to major muscle groups, facilitate enzymatic activity, and ready the body for more strenuous effort. Warm-up should begin with 5 minutes of low-intensity activity. This should be followed by approximately 5 minutes of slow, gentle stretching of the major muscle groups, particularly those most used during the exercise.

Exercise Period

The mode of exercise used during this period should be the mode used in the performance of the sports skill. However, the training effects induced by running, although specific, do appear to have beneficial cross-over effects for other groups. The purpose of this period is to cause specific and efficient biological adaptation to improve performance in specific events. Therefore, the muscle groups used for these events must be trained.

Cooldown

Like the warm-up period, this period has two components: low-intensity activity and some light stretching. The cooldown allows for proper recovery from exercise. This part of the conditioning allows the body to accommodate and adjust to the nonexercise mode. It allows the muscles to rid themselves of excess lactate buildup during the exercise period.

Progression

If an increase is contemplated in an exercise program, it should be accomplished slowly over a period. There should be no pain or history of recent injury before an increase is undertaken. Also, frequency, intensity, duration, and mode of activity should be increased one at a time and not at the same time. The 10% rule states that none of these should be increased by more than 10% per week.

Return From Injury

Patient compliance is easier to achieve, and there is less muscle atrophy and detraining if there is relative rest instead of absolute rest. Relative rest is when there is a decrease in the training regimen, but it still allows the athlete to train at a lower level without further damaging the injured area. Also, an alternative activity is a good option for some patients. For example, an athlete with a stress fracture, who cannot run without pain, can swim if possible.

Light-Intensity Training Program

This program allows an orderly stepwise return to a previous training regimen and incorporates the cooperation and help of the patient.

The three options to be considered are as follows:

1. If pain and/or swelling develops during the activity, stop all activity immediately, and decrease activity the following day by 25%.
2. If pain and/or swelling develops after the exercise is completed, continue the following day at the same level, but do not increase the level of activity.
3. If pain and/or swelling is not present during or after activity, increase the activity slightly.

Main Effects of Conditioning on the Human Body

Effects on the Heart

As the body begins to exercise, the muscles use oxygen at a higher rate, and the heart must pump more oxygenated blood to meet this increased demand. The heart is capable of adapting to this increased demand through several mechanisms. The heart rate shows a gradual adaptation to an increased workload by increasing proportionally to the intensity of the exercise and will plateau at a given level after about two to three times.

A second mechanism by which the heart is able to adapt to increased demands during exercise is increasing the stroke volume. Stroke volume is the volume of blood being pumped with each heartbeat. Stroke volume can continue to increase only to the point at which there is simply not enough time between beats for the heart to fill up.

Stroke volume and heart rate together determine the volume of blood being pumped through the heart in a given unit of time. This is known as cardiac output. After adequate conditioning, the heart becomes more efficient. This is because the heart will be capable of pumping more blood with each stroke. The stroke volume increases, while exercise heart rate is reduced at a given standard exercise load. Because the heart is a muscle, it will hypertrophy.

Effects on the Ability to Resist Fatigue

Fatigue is closely related to the percentage of maximum aerobic capacity that a particular workload demands. If aerobic capacity is impaired, fatigue will occur earlier. Exercise conditioning improves aerobic capacity. If an exercise program is too rigorous, the athlete can experience overtraining syndrome.

Effects on Muscular Endurance

Muscular endurance is the ability to perform repetitive muscular contractions against some resistance for an extended period of time. As muscular strength increases, there tends to be a corresponding increase in endurance. Muscle strength is a function of the number and diameter of muscle fibers composing a given muscle. Adequate muscle conditioning will increase the muscle strength and muscle endurance needed for different sports activities.

Effects on Flexibility

Flexibility is the ability to move a joint or series of joints smoothly and easily throughout a full range of motion. Some sports activities, such as gymnastics, ballet, diving, and karate, require increased flexibility for superior performance. An individual who performs stretching exercises to improve flexibility about a particular joint is attempting to take advantage of the highly elastic properties of a muscle. Over time, it is possible to increase the elasticity of a given muscle—the length it can be stretched.

Effects on Proprioception

Proprioception is a specialized variation of the sensory modality of touch that encompasses the sensation of joint movement and joint position. The ability to sense body position is mediated by cutaneous, muscle, and joint mechanoreceptors. A mechanoreceptor is a sensory receptor that responds to mechanical pressure or distortion. Injury and subsequent immobilization can affect the proprioceptors in the skeletal muscles, tendons, and joints. The proprioceptors are sensors that provide information about joint angle, muscle length, and tension, which is integrated to give information about the position of the limb in space. Some of the exercises used in conditioning stimulate and re-educate the proprioceptors.

Effects on Coordination and Balance

Coordination refers to the body's ability to execute smooth, fluid, accurate, and controlled movements. Coordination and proprioception are directly linked. Some conditioning techniques include activities that improve coordination. Some of these activities include constant repetition of motor activities or increasing the speed of the activity.

Balance is the ability to maintain the center of gravity of a body within the base of support with minimal postural sway. Poor balance has been significantly associated with an increased risk for musculoskeletal injury. Balance training as a part of the conditioning program appears to decrease the risk for musculoskeletal injury.

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See also Exercise Prescription; Exercise Programs; Resistance Training

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Congenital Heart Disease

A prime objective of preparticipation screening for athletics is to identify cardiovascular abnormalities that can cause sudden death. Congenital heart defects most commonly associated with sudden death include hypertrophic cardiomyopathy, coronary artery anomalies, Marfan syndrome, and aortic valve disease. Findings during preparticipation screening may raise clinical suspicion for cardiovascular disorders. The presence of a heart murmur or cardiac symptoms with exertion, such as chest pain, unusual shortness of breath, and change in level of consciousness, all may be of clinical significance. Also important is a family history of heart disease or sudden, unexpected cardiac death.

Hypertrophic Cardiomyopathy

Hypertrophic cardiomyopathy is the most common cause of sudden cardiac death in athletes younger than age 30. It is a genetic disorder causing mutations in an estimated 12 different genes. These gene mutations create abnormalities in the left ventricle muscle. Asymmetric thickening of the ventricular walls greater than 15 millimeters (mm) with no dilation or enlargement of the ventricle develops, causing possible obstruction of outflow from the ventricle with exercise. Changes in the ventricular muscle cells may also generate abnormal heart rhythms. Often a thickness of 13 to 14 mm is identified, placing the patient in a "gray zone," making precise diagnosis more difficult and requiring additional testing. Many hypertrophic cardiomyopathy patients are asymptomatic.

Symptoms such as syncope, chest pain, and shortness of breath may be noted. A murmur on exam and a family history of sudden cardiac death at age <50 also raises suspicion. Any athlete with symptoms, a suspicious murmur, or a family history of sudden death should undergo further evaluation. An echocardiogram (ECG) along with an electrocardiogram (EKG) is typically performed to assess for hypertrophic cardiomyopathy.

As the technology of genetic testing improves and becomes more readily available, it may be possible to identify athletes who are potentially at risk via genetic testing before clinical evidence appears. Athletes with a probable or definitive diagnosis of hypertrophic cardiomyopathy should be restricted from competitive sports.

Coronary Artery Anomalies

Congenital coronary artery anomalies are the second most common cause of sudden death in young athletes. The coronary arteries supply blood to the heart muscle tissue. In the normal heart, the left main coronary artery originates from the left side of the aorta and passes behind the pulmonary artery. From there, it leads to the heart muscle on the front and side of the heart, branching off into smaller arteries. The right coronary artery originates on the right side of the aorta and passes down the front side of the left ventricle, branching off to the back side of the heart.

Several types of anomalies have been identified. The most common malformation is anomalous origin of the left main coronary artery from the right side of the aorta, with a sharp-angled bend passing between the pulmonary artery and the aorta. This abnormal path may result in myocardial ischemia (lack of blood supply to the heart muscle) due to inadequate blood flow in the coronary artery or compression from the sharp-angled path between the two large blood vessels. Less common malformations involve anomalous origin of the right coronary artery from the left side of the aorta, coronary artery hypoplasia (incomplete formation), or anomalous origin of the left main coronary artery from the pulmonary artery, which carries poorly oxygenated blood.

Identifying these anomalies can be quite difficult, since patients often have no symptoms and EKGs at rest or with exercise are usually normal. Any athlete with symptoms of syncope or abnormal heart rhythm should be evaluated. Studies may include an ECG, a cardiac magnetic resonance imaging (MRI) scan, or a computed tomography (CT) scan, and possibly cardiac catheterization. Athletes diagnosed with anomalous coronary arteries should be excluded from competitive sports. Surgical repair should be considered, and if successful, showing no myocardial ischemia, the athlete may be allowed to return to sports.

Marfan Syndrome

Marfan syndrome is an inherited connective tissue disorder caused by more than 400 gene mutations. It occurs in 1:5,000 to 1:10,000 individuals in the general population. Abnormalities of the connective tissues can cause changes in the tissues of the skeleton, eye, aorta, and skin. Skeletal changes often generate suspicion of the diagnosis and include tall stature, arm span greater than height, scoliosis, and chest wall abnormalities.

The cardiovascular changes include weakening of the walls of the aorta, which places the athlete at risk of developing dilation and potential rupture of the aorta. Abnormalities of the heart valves may also develop. Complete evaluation, including EKG, ECG, and DNA testing, should be performed in any athlete suspected of Marfan syndrome. Those diagnosed with Marfan syndrome should not participate in vigorous dynamic or contact activities. Athletes should have repeat exams of the aorta every 6 months for close surveillance. They may participate in low-intensity exercise, such as golf or bowling.

Other Congenital Heart Defects

Many additional heart lesions can occur, including those of the heart valves, and are discussed elsewhere. Defects of the septum (the muscle tissue dividing the heart) can occur between the upper chambers (atria) or lower chambers (ventricles). Athletes with septal defects may be able to participate in sports after evaluation shows normal cardiac function. Coarctation of the aorta is a narrowing or obstruction of the aorta, which can lead to abnormal blood flow or high blood pressure. Most patients will undergo dilation or surgical correction for treatment. If repeat evaluation shows normal blood flow and blood pressure with exercise, the patient may be allowed to return to sports.

Numerous congenital defects can occur that pose a life-threatening risk in the newborn period. These lesions involve abnormal placement of major blood vessels or malformed atria or ventricles. Surgical correction is necessary to improve survival and ability to perform even normal activities of daily living. It is possible that some patients may be able to participate in some level of physical activity. The clinician must carefully assess the type of defect and the risk for sudden death with exercise. Also, the ability of the heart to perform under the demands of exercise without causing deterioration in function is central to determining eligibility for sports. Ongoing reevaluation of these patients annually allows for assessment of continued eligibility.

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See also Cardiac Injuries (Commotio Cordis, Myocardial Contusion); Physical Examination and History; Preparticipation Cardiovascular Screening; Presports Physical Examination; Sudden Cardiac Death

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Contusions (Bruises)

One of the most common sports injuries is a *contusion,* which results from blunt force trauma resulting in the accumulation of blood in tissue due to disrupted capillaries.

The contusion is noticeably different from *ecchymosis,* which is a bruise with significant discoloration but lacking swelling (edema). At the other end of the spectrum is the *hematoma,* which is a contusion with significant swelling due to accumulation of blood and serous fluid from the disrupted capillaries and tissues.

Mechanism and Symptoms

The contusion can vary in severity due to its size and location, especially in areas with richer blood supply. Most contusions result in some level of pain and discomfort, a result of the release of histamine and other anti-inflammatory chemicals into the spaces between the cells. Generally, the larger the contusion, the more blood is leaked into the intercellular space and the more discomfort is associated with it. Most contusions are self-limiting injuries and respond favorably to *r*est, *i*ce, *c*ompression, and *e*levation modalities (RICE) immediately after injury.

The spectrum of color changes associated with contusions follow the body's ability to remove the displaced elements of blood from the leaking capillaries. Initially, there is a reddish-blue color from hemoglobin concentrations, which advances to more blue-green hues from the breakdown of hemoglobin to bilirubin in the next week or so. From this, it tends to fade into a golden-brown color with the hemosiderin deposition from iron deposits in the intracellular tissue, finally resuming normal flesh tones.

Minor contusions may take a week or two to resolve, while more serious contusions can take longer. However, there are various contusions that will require more elaborate investigation and management as they can be found in critical tissue areas, such as organs, and can result in permanent disfigurement and dysfunction and sometimes death.

The following is a partial list of organ- and site-specific areas that can present with varied complications and consequences: the retina, ear (wrestler's ear), face, heart, lung, abdomen (liver, spleen, pancreas, intestines), vulva, testicle, bone, rotator cuff, and large muscles, such as the quadriceps, among many others. Several of these will be reviewed here.

Bone Bruises

A bone bruise is the result of blunt force trauma sufficient to disrupt the matrix of the bone just underneath its surface but not sufficient to fracture the entire bone. These injuries are typically associated with increased pain and injuries to adjacent ligaments or tendons. Imaging beyond radiographs, such as computed tomography (CT) and magnetic resonance imaging (MRI), is necessary to confirm bone bruises and also help identify associated injuries to adjacent ligaments or tendons. The natural history of a bone bruise suggests that it is a precursor to early degenerative changes (early arthritis). As such, it is important to delay return to full weight-bearing status in order to prevent further collapse of bone just beneath the surface (subchondral bone) and further aggravation of the lining of the joint spaces (articular cartilage).

Contusions to Large Muscles

Contusions to large muscles such as the quadriceps can result in significant disruption of the muscle belly and, due to its large size, can bleed extensively. One potential adverse complication of a quadriceps contusion is the development of myositis ossificans (heterotopic bone, bone that does not belong there) within the contusion, which can result in prolonged rehabilitation and muscle dysfunction and occasionally requires surgical intervention. The recommendation for this particular injury differs from others in that the knee is immediately placed into a flexed position of 120° and maintained in that position for 24 hours. It is felt that keeping the muscle stretched helps in reducing blood accumulation and also in decreasing contracture. Diagnostic ultrasound investigation of the size and type of echogenicity of the lesion is valuable in predicting the severity of the trauma, with anechoic and low-echogenic lesions taking longer to heal.

There have been isolated reports of delayed compartment syndrome (swelling that entraps the local blood vessels and nerves) following contusion to the thigh as well as other areas of the limbs, so serial monitoring of the size of the hematoma is prudent. Compartment syndromes can occur in any closed fascial space, such as an arm or a leg. A large contusion can create sufficient compressive forces, resulting in symptomatic pain, pallor, pulselessness, paralysis, and paresthesias that represent a suffocating limb. Urgent surgical fasciotomies are required to release the pressure.

Pulmonary Contusions

Pulmonary (lung) contusions are frequently associated with major chest trauma and may impair ventilation (breathing) due to derangements in the flow of air and/or blood. The forces associated with blunt thoracic trauma can be transmitted to the lung tissue. Athletes may complain of shortness of breath, rapid breathing, and chest pain, with blood-tinged sputum and low oxygen concentrations. Radiographs (X-rays) may show areas of small or diffuse patterns of congestion that do not fit the typical segmental patterns of pneumonia, and these are not evident until 4 to 6 hours after injury and may take up to 48 hours to appear. A CT scan of the chest can demonstrate these injuries immediately. Treatment consists of pain control, breathing exercises, and supplemental oxygen if there is low oxygen concentration in the blood. Larger contusions that interfere with oxygenation, leading to hypoxia and hypercardia, may require intensive medical care that may include being placed on a mechanical ventilator. The extent of low oxygenation typically parallels the degree of lung tissue involvement and contused lung volume seen on initial imaging studies.

Other Types of Contusions

Contusions to the heart muscle following blunt chest injury through violent contact in collision sports are rare but can have disastrous consequences such as cardiogenic shock (the heart failing to pump properly) if not evaluated thoroughly. Continuous EKG monitoring along with serial cardiac enzymes (blood tests of the leaking heart muscle) and echocardiography (sound waves showing heart motion) are necessary to assess clinical suspicion for this potential problem.

Blunt injury to the shoulders can result in contusions to the rotator cuff muscles. Most injuries will require conservative treatment, with a minority progressing to more severe injuries such as rotator cuff tears. An MRI scan can grade the severity and extent of injury, providing more useful information of the tendon's integrity to determine the prognosis.

Other contusions to organs are considered serious and need to be monitored medically. A contusion to the eye, kidney, liver, spleen, or testicle especially will require evaluation by a trained medical professional to ensure the best outcomes as there may be permanent loss of the organ if the injury is not monitored carefully and treated appropriately.

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See also Cardiac Injuries (Commotio Cordis, Myocardial Contusion); Hip Contusion; Lower Back Contusion; Pressure Injuries to the Skin; Rib Fracture and Contusions; Thigh Contusion

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Core Strength

Critical for both stability and movement, the core includes muscles of the spine, abdomen, hip, and shoulder. Over the past 20 years, there has been growing interest in the area of core stabilization for the prevention and rehabilitation of back injuries as well as for the enhancement of athletic abilities. For example, it is now known that weakness of the pelvic muscles is a predictor of back pain in the college athlete. It has also been shown that sports performance is related to the strength of pelvic musculature and proper activation of the abdominal and back muscles.

However, debate continues over the exact definition of the core and the most effective methods of stabilization. Some authors have divided the core into the upper quadrant core and the lower quadrant core. The upper quadrant core refers to the shoulder girdle, including the glenohumeral joint (the shoulder joint) and the scapulothoracic articulation (the area of contact between the shoulder blade and the upper back). The lower quadrant core muscles include those of the spine, abdomen, and hip.

Power for many athletic movements is generated in these core muscles. Adequate power must be created and transferred efficiently from the core to the limbs for the system to work at maximal capacity. In the overhead throwing athlete, the transfer of force from the lower quadrant core to the upper quadrant core is essential for effective throwing.

These muscles must be both strong and well coordinated to provide stability and allow the athlete to adapt rapidly to changing conditions on the field of play. Therefore, they are a crucial aspect of training and rehabilitation programs. A large variety of exercises are classified under the category of "core stabilization," and the importance of specific components of core stabilization is an area of ongoing study. Combinations of muscles are used for different tasks, and in general, it is recommended that athletes not focus solely on individual muscles but instead address muscle groups and functional motor patterns.

Anatomy

Lower Quadrant Functional Anatomy

The lower quadrant core muscles include spinal, abdominal, and hip muscles that help support and position the spine. The spinal muscles include the erector spinae, multifidus, and quadratus lumborum and a variety of other muscles. The erector spinae work to bend the trunk backward (extend the spine). These muscles are located at the back. They originate at the level of the tailbone (sacrum) and divide into three bands on each side of the spine. They attach at different spinal levels and the back of the skull.

The multifidus muscle and the quadratus lumborum also extend the back when activated on both sides of the spine. When activated unilaterally, they bend the trunk to one side. The multifidus are shorter muscles that come in pairs on each side of the spine, located along the entire length of the spine. Each multifidus spans only two to three vertebral levels and, therefore, works to compress and carefully control the small, segmental motion of the spine. Conversely, the quadratus laborum originates at the back of the pelvic bone at the iliac crest and attaches to the 12th rib and the first four lumbar vertebrae (L1-L4). This provides a longer lever arm of extension but with less control over individual segments.

The abdominal muscles work together to flex the spine and assist in rotation. These muscles include the rectus abdominus and the three layers of the abdominal wall with the internal and external obliques and the transversus abdominus. The rectus abdominus is one of the main muscles involved in bending the body forward. One of the first muscles activated with power motions is the transversus abdominus, which attaches directly to the thoracolumbar fascia in the back. The coactivated abdominal, oblique, and back muscles work together to stabilize the spine.

The internal and external obliques flex the body forward when they are fired on both sides of the body. When fired unilaterally, they cause the body to bend to one side and rotate. Because the oblique muscles are connected to the torso and the pelvis, they are important in the rotation of the body, especially during sports participation.

The hip muscles are important in pelvic stability and for rotating the hips and legs. The piriformis, the obturator internus and externus, and the superior and inferior gemellus act to turn the hip outward. The gluteus maximus extends the leg back and rotates the upper leg outward. The gluteus medius and minimus rotate the upper leg inward. The gluteus medius acts primarily to abduct the hip, moving it away from the body.

Upper Quadrant Core

The upper quadrant core is important for transfer of forces to the upper extremities. For the glenohumeral (shoulder) joint to function properly, the scapula (shoulder blade) must be in proper position. The serratus anterior and trapezius rotate the scapula. The serratus anterior originates on the side of the ribs and attaches to the scapula. The trapezius originates from the back of the skull, the cervical vertebra, and the thoracic vertebra and attaches to the clavicle and scapula.

It has been suggested that there are several muscle "slings" that coordinate and stabilize the motion of the upper and lower core quadrants. These slings cross from one side of the body to the other and transfer forces from the lower to the upper extremity via the core stability system. The posterior oblique sling is composed of the latissimus dorsi on one side of the body and the gluteus maximus on the opposite side through the thoracolumbar fascia. The anterior oblique sling is made from the connection of the external oblique on one side of the body and the internal oblique on the opposite side, through the abdominal fascia.

Evaluation and Rehabilitation

Strong and balanced core muscles support the spine and reduce any stress that can lead to injury. Weakness in any part often leads to compensation, resulting in a less efficient movement and an increased risk for injury. Weakness in the core or poor energy transfer can lead the peripheral muscles to be overtaxed in their effort to generate adequate power. The entire chain of sport-specific movement should be evaluated and any deficit addressed.

The evaluation is ideally done preseason according to a standard protocol to assess each of the core components. To begin, the standing posture can be informative. For example, deep lumbar lordosis with a forward tilted pelvis (also called sway back) may indicate weak abdominals. A single leg squat can evaluate pelvic strength: With the hands on the hips, the athlete is instructed to keep the hips level and shoulders upright. If the hips tilt to one side while squatting, the hip abductors (gluteus medius) are weak. If the athlete leans forward, the hip extensors (gluteus maximus) are weak. A jump drop test is also very helpful for evaluation of these muscles: The athlete is asked to jump up off a box and onto the floor. If the knees collapse inward during the landing, the hip abductors are weak. Abdominal strength may be assessed with an abdominal brace test: Lying on the back with the knees bent 90° and the feet held flat by the examiner, the athlete is asked to hold a sit-up in 60° of flexion until fatigued.

Flexibility, important for fluid motion of the pelvis in synchronization with the lumbar spine, should also be assessed. Key muscles for evaluation include the hip flexors and the hamstrings.

When an athlete suffers an injury, the core should be assessed along the entire kinetic chain. Rehabilitation follows a specific sequence from the acute phase of rest and gentle range of motion, to the longer rehabilitation phase of strengthening and conditioning, and finally to the sport-specific phase. In the strengthening phase, the areas of known weaknesses are addressed first in a more isolated manner and then as part of coordinated motions. The final, critical phase of sport-specific movement gradually reintroduces the athlete to those activities necessary for full return to play.

Good neuromuscular control is also necessary to coordinate movement. Proprioception (the body's awareness of spatial positioning) is an important part of this neuromuscular control. The balance ball is one tool used in proprioceptive training. This type of training should be initiated early and continued throughout the rehabilitation process.

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See also Exercise Physiology; Exercise Prescription; Resistance Training

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Corns

A *corn* is a buildup of skin located on the top, side, or end of the toe or between two toes. Corns are caused by constant friction against the shoe or between two toes. They are actually a normal and natural way for the body to protect itself, by thickening of the skin in response to increased pressure. They may be soft or hard, depending on their location. Most corns on the top of the toes are hard, while those in between toes are soft. Other names for corns are hyperkeratosis, clavus, and heloma.

Diagnosis

History

A patient will usually present with a corn when it becomes painful due to the buildup of excess skin and increased pressure. Increased pressure can result from shoes that are too tight, toe deformities such as hammertoes, bony prominences on the toes, or biomechanical or gait abnormalities that cause the toes to flex, or bend, while walking.

Common sports and dance activities may predispose an individual to the development of corns. Ballet dancers have an increased tendency to develop corns due to the tightness of the pointed shoes they wear.

As there is a whole range of causes for corns, it is important to note that corns are merely the symptom of an underlying condition.

Physical Examination

Corns can be recognized on visual examination of the foot. The doctor will likely evaluate the underlying cause of the corn, such as a bony deformity. A gait analysis and inspection of footwear may be performed to evaluate for any contributing factors of increased pressure.

Occasionally, fluid may develop underneath a corn, causing a painful condition. Drainage of this fluid usually decreases the painful symptoms. Additionally, the fluid can be located deeper, underneath the skin. *Bursitis,* a painful, inflamed, fluid-filled sac, can develop deep beneath a corn.

Imaging Studies

Radiographs (X-ray films) of the foot may be taken to evaluate the presence of any bony deformities. This will assist in the diagnosis and help direct appropriate treatment of the corn.

Treatment

Initial treatment will likely involve scraping the excess skin from the corn to reduce the pressure and decrease the pain symptoms. Additionally, any fluid causing pain can be drained. The doctor may also recommend methods of trimming the corns at home with a pumice stone to prevent recurrence.

Padding of the corns with over-the-counter pads may decrease irritation of the skin. Generally, the medicated type of pads should be avoided, as they may cause acid burns to the skin.

When conservative treatment fails to resolve the pain symptoms, addressing the underlying deformity may be necessary. This may involve surgical correction of the hammertoe or removal of the bony prominence.

Prevention

Corns and calluses can usually be prevented by avoiding friction-causing activities and wearing shoes that fit properly, are activity appropriate, and are kept in good condition. Soles and heels that wear unevenly may indicate a need for corrective footwear or orthotics.

Return to Sports

An athlete may return to sports once the pain symptoms resolve. Depending on the underlying cause, supportive foot devices called orthotics or special padding may be ordered to prevent recurrence of the corn.

Thanh Dinh

See also Athletic Shoe Selection; Bunions; Foot Injuries; Orthotics; Podiatric Sports Medicine

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Costosternal Syndrome (Costochondritis)

Chest pain can result from a broad range of causes, including both musculoskeletal and nonmusculoskeletal etiologies. Pain due to musculoskeletal causes can arise from the cartilage, bones, muscles, nerves, or joints that make up the chest wall. *Costochondritis* is one of the most common causes of chest wall pain and refers to inflammation in the costochondral or costosternal junction; it is also known as *costosternal syndrome.* Up to 30% of cases of chest pain that present to the hospital emergency room may be explained by costochondritis. However, it is a much more benign diagnosis than many of the causes of chest pain diagnosed in emergency facilities.

Costochondritis is slightly more common in females than in males, but it occurs in both. It is not isolated to the athletic community. It can occur in both children and adults, although it is more commonly seen in individuals 40 years and older. It can result from repetitive trauma, or it can be due to a particular incident that places strain on the costochondral region. The level of physical activity in affected individuals can range from very active to very sedentary. In various instances, it has been known to result from repetitive coughing. It most commonly occurs between the second and fifth ribs and can involve one or more ribs at the same time. Recognizing costochondritis is important because it is benign and should be distinguished from more serious causes of chest pain, which would be more worrisome.

Anatomy

The chest wall is made up of 12 ribs. Ribs 1 through 7 are referred to as true ribs, and they are attached to the sternum (the breastbone) via a cartilaginous tissue known as *costochondral cartilage* (also known as costocartilage). The joint between the sternum and the costochondral cartilage is known as the *costosternal joint*. The joint between the ribs and the costochondral cartilage is known as the *costochondral joint*. Ribs 8 through 10 are called false ribs because they are indirectly attached to the sternum via the costochondral cartilage of the ribs above them. Finally, Ribs 11 and 12 are called the floating ribs because they are not attached to the sternum at all. In the back, or posterior side, the ribs are attached to the spine. The *intercostal muscles* are the muscles located between the ribs; they help support the rib cage and participate in the chest wall movement that facilitates breathing. The intercostal nerves and vessels are located under the ribs. Various other muscles attach to the ribs from other angles and help support and move the adjacent structures, including the neck, arms, back, and chest. Therefore, repetitive upper body activity can lead to pain and overuse injuries affecting these various structures that make up the chest wall (see Figure 1).

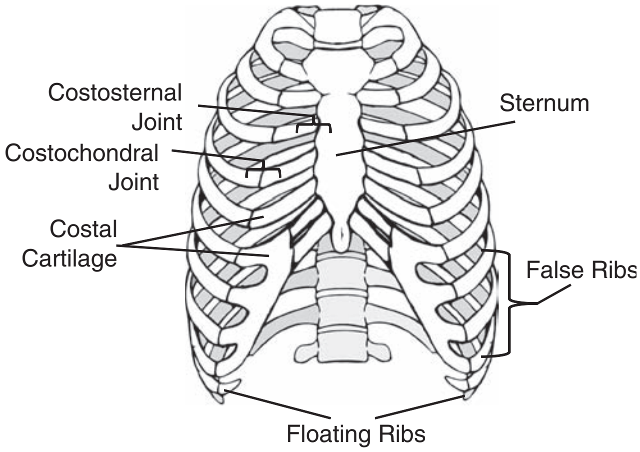

Figure 1 Anatomy of the Rib Cage

Diagnosis

Costochondritis is associated with sharp chest wall pain, often worsened by taking in a deep breath, coughing, and various movements affecting the rib cage, such as moving the arm around. One or more costochondral or costosternal joints can be involved, and the primary source of pain will arise from these structures. Placing direct pressure on the affected costochondral or costosternal joint will exacerbate, or bring out, the pain that the individual is having, although sometimes this is difficult to identify during the examination. There is no swelling or fever or deformation associated with this condition. The skin overlying the affected region should be normal in appearance and not associated with heat.

The diagnosis is made clinically—that is, by physical exam and history alone. No studies are needed unless an alternative diagnosis is being considered or if there is suspicion of something more serious. X-ray findings will be negative, but they may be ordered in select circumstances when other etiologies are being considered.

Costochondritis is a benign condition that does not predispose one or more serious issues. Thus, if the pain worsens, if it is related to difficulty breathing or feeling lightheaded, or if the pain is really severe, then a physician's attention should be sought urgently to exclude more serious causes.

Treatment

Costochondritis is a self-limiting diagnosis. It usually resolves within several weeks to months. Management includes taking analgesics to treat the pain, especially anti-inflammatory medication such as naproxen or ibuprofen, and minimizing activities or repetitive motions that worsen the pain. Acetaminophen can be used if the individual cannot take anti-inflammatories. Sometimes, placing a heating pad on the affected area may be helpful.

Other Causes of Chest Wall Pain That Can Mimic Costochondritis

A number of etiologies can cause chest wall pain apart from costochondritis and may need to be considered or ruled out to make an appropriate diagnosis. These are discussed below.

Tietze syndrome is the most common alternative diagnosis that can be confused with costochondritis. It occurs in any of the cartilaginous joints of the chest wall but most commonly is located at Rib 2 or 3. The sternoclavicular joint can be affected as well. Unlike costochondritis, there will be obvious swelling in the affected region. The pain will often radiate down the arm or shoulder and can last for several weeks. In severe cases, aspiration (placing a needle into the pocket of inflammation to take a sample) or a biopsy may be needed to exclude infectious causes. X-rays will often be normal, but the involved area will light up on bone scan imaging. The condition occurs most often in young people and is self-limiting and benign. It is treated with analgesics and anti-inflammatories and resolves on its own. Severe cases may require a local injection of corticosteroid.

The *intercostal muscles* can be injured as a result of sport activity if the rib cage is moved in an awkward position or if too much strain is placed on the muscles. This will be characterized by tenderness located on the muscles between the ribs as opposed to the costochondral joint. This entity is more common in sports that involve repetitive overhead activity, such as rowing. The pain can worsen with deep breathing, coughing, and overhead motions and can be treated with analgesics.

Precordial catch syndrome occurs mostly in teenagers and young adults below 35 years of age. It refers to sudden, sharp, stabbing pain that lasts several seconds and is most often located in the left upper chest wall region. It often occurs at rest or with change in activity. The pain is often relieved by stretching or changing one's posture. It can occur multiple times a day and can worsen with deep breathing. It is benign, and there is no known treatment.

Pleurodynia, also known as *epidemic myalgia, Bornholm disease,* and "*devil's grip,*" is caused by a viral infection. It presents as a sudden, sharp, severe pain in the lower chest or upper abdomen. The pain often worsens with coughing or deep breathing. However, unlike costochondritis, it is associated with fatigue, fever, headache, and other signs of a viral illness. It is self-limiting and should resolve within several days to a week. Although it is most often due to the Coxsackie virus, it can result from a variety of viral syndromes. For pain relief, anti-inflammatories or a heating pad can be used.

Stress fracture refers to a microtear in bone that has sustained repetitive trauma. It can occur in any bone, especially in athletes. This diagnosis should be considered in any athlete with severe rib pain, especially in athletes participating in sports involving frequent overhead activity, such as rowing, golf, tennis, swimming, javelin throwing, or weight lifting. X-rays may be normal early on in the disease, so a bone scan is often required to identify the affected location, which will light up. The athlete will need to stop sports activity for the injury to heal, and this can take up to 6 to 8 weeks. The pain associated with a stress fracture is often much more severe than in costochondritis and usually results in a noticeable limitation of movement in the affected individual.

Slipping rib syndrome is known by multiple other names, including painful rib syndrome and rib tip syndrome. It begins with a sharp stabbing pain that lasts only several minutes, followed by several days of a dull ache. The pain is specifically located under the rib cage. It can be associated with a sensation that the rib is slipping or popping out as a result of moving in various positions. Sometimes a "clicking" sound can be heard. Often palpation of the costal margin will bring out the pain. Slipping rib syndrome will not be visible on any type of imaging. It is believed to result from hypermobility of the floating ribs, which are believed to be slipping underneath the rib located above. It is benign and usually resolves within 4 to 6 weeks. Sometimes taping the area can be helpful.

Rarely, chest wall pain can result from a *costal cartilage fracture.* This is characterized by the sudden onset of sharp pain during sports activity, and tenderness is localized to the costal cartilage itself. Occasionally, it is associated with a painful "click." Most imaging will be unrevealing, but a computed tomography (CT) scan can be helpful in making the diagnosis. Surgery may be required for treatment.

Herpes zoster is a virus that can invade the nerves in a specific distribution (known as a dermatome) and causes painful skin rash associated with a burning sharp pain. Unlike costochondritis, it is associated with a characteristic rash, but during its early stages, the rash may not be evident, and it may be confused with musculoskeletal causes of chest wall pain.

Nonmusculoskeletal causes of chest pain can be more serious than costochondritis and, therefore, should be ruled out in the appropriate setting, especially in older adults. Chest pain can result from various thoracic organs that include, but are not limited to, the heart, lungs, aorta, and esophagus and from the pleural lining of the lung.

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See also Chest and Chest Wall Injuries; Organ Injuries; Stress Fractures

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Cramping

Cramping in athletes is frequently referred to as *exercise-associated muscle cramps* (EAMC) and is the term used to describe the painful, involuntary contraction of skeletal muscle. EAMC are a common complaint among endurance athletes and those who compete outdoors in hot, humid environments. While the exact cause is unknown, many factors are believed to contribute to EAMC, including dehydration, electrolyte depletion, and muscle fatigue. Cramping has been reported in athletes of every sport and can occur in athletes of any age, race, or gender. Contractions can be visible and palpable and can affect a single muscle or an entire muscle group. Cramping may occur during or immediately after exercise. After cramping, it is common to have muscle soreness for 2 to 3 days.

The diagnosis of EAMC is made clinically, and the most effective immediate management of EAMC is rest and passive stretching. The key to the prevention of EAMC is to reduce the risk of developing premature muscle fatigue, dehydration, and electrolyte depletion. Skeletal muscle cramping is one of the most common conditions that require medical attention during sporting events.

Etiology

There are many theories as to the cause of EAMC, but none has been universally accepted. Some of the more common theories include electrolyte depletion, dehydration, and muscle fatigue. Because electrolytes, such as sodium, potassium, and magnesium, play vital roles in the physiology of muscle contraction, depletion of any of these elements through increased sweating or urination could inhibit proper contraction of the muscle. Dehydration could also play an important role in skeletal muscle cramping, because water has many important functions in muscle physiology and is an important method of thermoregulation in the body. A third hypothesis for the etiology of EAMC is muscle fatigue, which leads to altered neuromuscular control. The increased excitation of muscle spindles and the reduced inhibitory response of Golgi tendon organ activity could lead to abnormal neuromuscular excitability, which could cause the muscle to cramp. Muscle fatigue could also be caused simply by exercising at a level of higher intensity or duration than is standard for the athlete. There is literature to support all three of these hypotheses.

From a historical perspective, stokers on ships mixed seawater with drinking water to fend off cramps. Heat cramping and exhaustion were reduced when a saline drink was given to industrial stokers and coal miners in England. It has also been shown that the sweat sodium levels of athletes who cramp are significantly higher than in those who do not cramp. The exact mechanism for cramping from sodium loss is not clear. What is known is that sodium loss reduces extracellular fluid space and may alter ion channels to make neuromuscular junctions or muscle units hyperexcitable, causing involuntary and sustained contractions, or EAMC.

It is also important to recognize that skeletal muscle cramps can be associated with numerous congenital and acquired conditions, including hereditary disorders of carbohydrate and lipid metabolism, neuromuscular and endocrine diseases, medicines, and toxins. There are several risk factors that may be associated with the development of EAMC. However, the most important intrinsic risk factors for EAMC are a previous history of EAMC, current hydration status and electrolytic balance, and performing exercise at a higher intensity or for a longer duration than normal training. Participating in hot and humid environmental conditions is the most important extrinsic risk factor.

Diagnosis and Treatment

Muscle cramping in athletes has a classical presentation, and the diagnosis is made based on history and clinical examination. Special tests are usually not indicated. EAMC typically occur in athletes earlier in the season, when they have just begun their training; toward the end of a strenuous workout; and when athletes are unacclimatized to exercising in hot, humid conditions. Cramping is usually preceded by a noticeable twitching of the muscle, which develops into spasmodic contractions and then frank muscle cramping. This is usually associated with pain and continues until the activity is stopped and the muscle is stretched. Typically, muscle cramping is confined to muscle groups that are used during exercise, such as the calf muscles, hamstring muscles, and quadriceps muscles.

EAMC can be treated initially by stopping exercise and passively stretching the muscle. This stretching increases the tension in the muscle, thereby increasing the inhibitory activity of the Golgi tendon organ. Passive stretching is the most effective treatment for a cramping muscle and should be maintained until cramping of the muscle or muscle group ceases. Massage of the cramping muscle is sometimes useful as well. It is important for the athlete to rest for a short period of time before returning to exercise. Other common treatments include ice massage and intravenous or oral fluids containing electrolytes. Ice massage cools the muscle, while the massage component that can be beneficial as well. EAMC can often be reversed fairly quickly with 2 to 3 liters (L) of intravenous normal saline.

After acutely evaluating the athlete, a thorough physical exam should follow. The examiner should visually inspect the involved muscles, which includes looking for a hard contracted muscle or visible fasciculation. Usually, there is no other abnormality seen on physical exam. In patients with chronic cramping problems, a full musculoskeletal and neurological evaluation should be performed. It will be important to rule out other causes of cramping by obtaining a complete family and personal history, including a history of diabetes, metabolic disease, cramping, and prescription and over-the-counter medicines.

Prevention

The exact causes of EAMC are still being debated, and there is no treatment that will work for every patient, every time. However, in patients with chronic cramping problems, a thorough evaluation of exercise warm-up, training, and cooldown habits; diet; and game-day routine will be important to identify any possible conditions that may lead to cramping. Ensuring a normal training and game-day routine will be an important part of knowing what to change in order to help athletes overcome the cramping problem. Assessing the athlete's diet will also be a vital part of treating and preventing cramping; proper hydration, carbohydrate and electrolyte supplementation, and a balanced diet should be encouraged as well. There is some literature that suggests that supplements such as creatine may increase the risk of cramping because of the small amount of fluid retention in the muscle caused by the supplement.

Another important consideration for teams who experience problems with cramping will be to alter the time or environment in which they practice and play. Practices should be scheduled during early-morning or early-evening hours, avoiding the middle of the day, when temperature and humidity are at their highest. Having plenty of rest periods, and times and methods of cooling players off, will also be helpful. Also, it takes time to become acclimatized to the heat and humidity, so by gradually increasing the workout intensity, athletes should experience fewer episodes of cramping. The key to the prevention of acute EAMC is to protect the muscle from developing premature fatigue during exercise by maintaining a balance of electrolytes and proper hydration.

Conclusion

There is a high lifetime prevalence of EAMC in athletes, specifically in endurance athletes. While the exact cause is unknown, there are many factors that are believed to contribute to EAMC, including dehydration, electrolyte depletion, and muscle fatigue. The most important intrinsic risk factors for EAMC in athletes are a previous history of EAMC and performing exercise at a higher relative intensity or for a longer duration than in normal training. The most important extrinsic risk factor is participating in hot and humid environmental conditions. The diagnosis of EAMC is made clinically, and the most effective immediate management of EAMC is rest and passive stretching. Athletes presenting with recurrent episodes of EAMC require a comprehensive examination. The underlying medical causes of cramping must be excluded in these athletes. The key to the prevention of EAMC is to reduce the risk of developing premature muscle fatigue by maintaining proper electrolyte balance and hydration.

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See also Heat Illness; Temperature and Humidity, Effects on Exercise

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Craniofacial Injuries

The prevalence of sports-related facial injuries has increased over the past several years, accounting for up to one third of all facial injuries encountered by maxillofacial specialists according to recent studies. Thus, the ability to care for an athlete suffering facial trauma has become an important part of sideline coverage. In this entry, we will discuss key components of the evaluation and management of the most common facial injuries.

The proportion of sports accounting for facial fractures varies according to the regions of the world and the popularity of sports with high contact and lack of protective facial equipment. Baseball, basketball, and racquet sports account for the majority of injuries in the United States, while soccer is overwhelmingly the leading cause in most of Europe. Rugby and cricket are the most common causes in the United Kingdom, Australia, and New Zealand.

The most common sites of injuries vary according to studies, with some showing that nasal and zygomatic fractures are most common while others show that mandibular and orbital fractures are more prevalent.

Acute assessment of an athlete suffering from facial trauma should start with the ABCs of basic life support. The airway should be kept patent from bleeding, and hemodynamic status should be assessed. A rapid neurologic assessment should be done as well to rule out concomitant head and neck injury.

Nasal Injuries

Nasal fractures are among the most common facial fractures, accounting for up to 40% of the cases of facial trauma. Fights, sports, and motor vehicle accidents are the most common causes. Bony anatomy of the nose includes the paired, wedge-shaped nasal bones; the nasal processes of the frontal bone; and the maxilla. The lower half of the nose is supported by lateral cartilaginous tissues and the midline nasal septum. The septum becomes increasingly thin and requires less force to fracture than any other facial bone. However, fractures of the base of the nose require more force and are often associated with other facial fractures.

Direct frontal blows cause depression and telescoping of the fractured bones posteriorly. Lateral blows can cause ipsilateral depression and contralateral protrusion of the fractured bone. As stated earlier, cervical spine injuries and airway compromise can result from facial trauma and should be evaluated. Significant bleeding can also occur from nasal fractures, with the anterior ethmoid artery causing anterior bleeding and the sphenopalatine artery causing posterior bleeding. Red flags in the evaluation of nasal fractures are cerebrospinal fluid (CSF) rhinorrhea, subcutaneous emphysema, malocclusion, limited extraocular movements, and mental status changes, any of which should prompt transfer to the emergency department. It is important that the examiner on the field be alert for nasal discharge of any clear fluid after facial trauma, which could suggest a CSF leak.

Once the initial assessment has been done and ABCs, neurologic status, and concomitant facial fractures have been evaluated, the focus can be turned to addressing the nose itself. Examination of external soft tissues and internal structures may be impeded by soft tissue swelling, ecchymoses, and blood. Fortunately, uncomplicated nasal fractures can be reduced in 3 to 5 days once swelling has subsided. However, examination of the nasal septum should be done at the time of injury to rule out septal hematomas. Septal hematomas are blood-filled cavities between the cartilage and supporting perichondrium. If left untreated, they can become infected and lead to necrosis and perforation of the septal cartilage, possibly leading to a permanent saddle nose deformity.

Internal inspection will require adequate lighting, suction, topical anesthesia such as lidocaine, and vasoconstrictors such as oxymetazoline (Afrin). If visualized, the hematoma should be aspirated or incised, and then a sterile gauze and splint or nasal packing should be used to prevent reaccumulation. Once stabilized, a final exam should be done, and the patient should be referred for otolaryngology or plastic surgery follow-up in 3 to 5 days.

Orbital Fracture

One third of orbital fractures are caused by sports activity, which trails only assault as the leading cause. In the United States, baseball is the leading cause, while in the United Kingdom and Australia, soccer and rugby are the major culprits. The major mechanism of injury is blunt trauma from either a projectile or an opponent's body part.

Orbital fractures may involve the orbital floor alone or a larger portion of the orbital rim. Damage to the orbital rim often requires a direct blow to the bony orbit, while an isolated orbital floor fracture results from direct trauma to the globe, with subsequent buckling of the orbital floor due to increased intraorbital pressure. The latter injury is often referred to as an orbital blowout fracture and affects the thinnest portion of the orbital floor, the posteromedial portion.

Evaluation of the athlete should include assessment of the bony orbit, globe, extraocular movements, and visual acuity, as well as a fundoscopic exam. A grossly ruptured globe should be protected from any pressure or direct contact by using a rigid shield, and the patient should be immediately transported to the emergency room. Foreign bodies should be left undisturbed, and an eye patch should not be used. Loss of vision and severe eye pain precluding examination should also prompt emergency ophthalmologic evaluation.

Diplopia and deficits in upward gaze may be a sign of an orbital blowout fracture in which the inferior rectus or oblique muscle have become entrapped in the orbital floor defect. Medial wall fractures may cause entrapment of the medial rectus, limiting lateral gaze. The orbital rim should be palpated to assess for gross deformity or crepitus; the latter may indicate subcutaneous emphysema from a sinus fracture. Numbness of the cheek and lateral nose may indicate injury to the infraorbital nerve.

The imaging study of choice for orbital injuries is a computed tomography (CT) scan of the face and orbits. Orbital plain films are not recommended, as some studies have shown a false-negative rate as high as 50%. Once ocular emergencies have been ruled out by careful examination and a CT scan, treatment of isolated orbital floor fracture may consist of early surgical repair or conservative management. Indications for early surgical repair are deficits in gaze, fractures involving greater than 50% of the orbital floor, globe malposition, and enophthalmos (backward displacement of the globe into the orbit) of greater than 2 millimeters (mm). Conservative management should include regular follow-up and may include prophylactic antibiotics and oral corticosteroids to help limit infection and fibrosis, respectively. Return to play following surgery is usually within 6 weeks with protective eyewear. The most common chronic complication of orbital fractures is diplopia.

Maxillary and Mandibular Fractures

Maxillary and mandibular fractures are primarily caused by motor vehicle accidents and assault, with sports accounting for 2% to 8% of these fractures. Maxillary fractures are classified by the Le Fort classification system. Le Fort I fractures are transmaxillary, with complete separation of the maxilla from the rest of the facial bones. Le Fort II fractures are through the nasoorbitolethmoid complex and are also referred to as pyramid fractures because on exam the maxilla and nose move together as a pyramid-shaped complex. Le Fort III fractures are complete craniofacial separations. The most common sports-related maxillary fracture is a non–Le Fort fracture called a tripod fracture. It is a zygomaticomaxillary complex fracture (ZMC), resulting in complete separation of the zygoma from the rest of the face.

Examination of maxillary fractures may reveal a flattened face, a lengthened face, ecchymosis, paresthesias, crepitus, and often malocclusion. Examination may also reveal limited gaze due to entrapped extraocular muscles, decreased visual acuity due to propagation of the fractured fragment into the orbital canal, or restricted mandibular motion from an inferiorly displaced fragment. Special care must be taken in Le Fort III fractures of airway compromise from posteriorly displaced tissues. Evaluation is done with a facial bone CT, and treatment is often with maxilla-mandibular fixation to reestablish dental occlusion, followed by midface restoration.

Mandibular fractures can be classified as single, multiple, fragmented, or avulsive. The most common locations are at the condyle and angle of the mandible. Examination should include the skin, oral mucosa, dentition, and palpation of the mandible for step-off or mobility of specific segments. Examination may reveal trismus, crepitus, malocclusion, lip and chin paresthesias, and inferior facial asymmetry. Acute management should involve use of a Barton bandage to immobilize the lower jaw for transport. Treatment is by surgical fixation.

Conclusion

Facial trauma is becoming increasingly common in sports. Initial assessment should focus on the ABCs and neurologic exam. Care should be taken to evacuate nasal septal hematomas as early as possible. Orbital trauma, extreme pain, deficits in gaze, and diminished visual acuity should prompt immediate ophthalmologic evaluation. Most athletes will require transport to the emergency room and imaging in the form of a facial CT scan. Return to play will be based on the level of trauma and specific surgical intervention.

Rahul Kapur

See also Dental Injuries; Facial Injuries; Head Injuries

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Creatine

Creatine is a popular, legal, over-the-counter dietary supplement that athletes use in preparation for sports and during training. It is not a steroid or stimulant but has been known since the early 1900s to have ergogenic properties. It became widely available and popular in 1993. Creatine is typically used to gain weight and muscle mass and to enhance strength training. It appears to be helpful by improving performance in short bursts of intense exercise, such as bench press or sprint cycling. It has no benefit on endurance in aerobic exercise. There is speculation suggesting that creatine supplementation may even help in improving mental performance, but this is still under debate.

The exact mechanism by which creatine supplementation improves athletic performance is not exactly clear, although there are several theories. Creatine seems to help athletes recover from vigorous exercise. The body uses creatine to make phosphocreatine, which acts as a buffer to keep up the production of ATP (adenosine triphosphate). ATP is the fuel used by the muscle during exercise, and the by-product is ADP (adenosine diphosphate). Creatine, among other things, essentially helps regenerate ADP back to ATP, thus replenishing the muscle's energy stores. There can also be weight gain and increased muscle mass with creatine use, up to 2.5 pounds (lb)/week (1.13 kilograms [kg]/week). Some proportion of this is likely due to water retention.

Creatine, in the monohydrate form or ethyl ester (CEE), is available as a sports drink powder or in a capsule form. The average daily intake of creatine from nutritional sources is about 1 gram (g)/day. It is found naturally in meat and fish. Creatine content in beef is approximately 4.5 g/kg. Tuna has about 4 g/kg, and herring has about 6 to 9 g/kg.

There are no universally agreed-on dosing or duration schedules, but there are some general recommendations. Most agree that the previously suggested "loading doses" of 20 to 30 g/day of creatine supplementation over a period of a week are not needed. They seem to increase potential side effects without giving significant benefits. In general, a maintenance dose of 3 to 5 g/day (or 0.03 g of creatine/kg of body weight), with no loading dose, is suggested. Many athletes cycle creatine use, using it for 3 months at a time followed by 1 month without creatine use. The optimal time to take creatine is immediately after a workout, combined with a drink with a high glycemic index (e.g., a commercial sports drink).

Short-term use of creatine is considered safe but can still have potential side effects. The most common side effects are bloating, diarrhea, and possibly muscle cramping. These effects can be minimized by forgoing the loading dose and staying well hydrated. Creatine does not seem to adversely affect kidney function but is not recommended for athletes with preexisting kidney disease. Because there is a lack of research in the pediatric population, creatine is not recommended by the American College of Sports Medicine (ACSM) for athletes under 18 years.

Michael O'Brien

See also Doping and Performance Enhancement: A New Definition; Doping and Performance Enhancement: Historical Overview; Doping and Performance Enhancement: Olympic Games From 2004 to 2008; Performance Enhancement, Doping, Therapeutic Use Exemptions; World Anti-Doping Agency

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Credentialing for Team Physicians

Medical education in a medical school, residency, and fellowship provides a physician with the scaffolding to provide appropriate care for athletes. Continuing medical education and years of experience are essential for a team physician to establish credibility in treating active individuals.

Becoming a Physician

A physician is an individual who holds an unrestricted medical license and the degree of Medical

Doctor (MD) or Doctor of Osteopathic Medicine (DO). To become a physician, one typically completes an undergraduate degree before attending 4 years of medical school. Classroom didactics constitute the first 2 years of medical education, and the final 2 years include both required and elective medical rotations. On medical school graduation, a person is considered a physician but cannot practice unrestricted medicine. The physician must pursue a residency in a medical specialty. The first year of residency training is called the internship year. Residency training lasts from 3 to 6 years depending on the specialty. After successful residency graduation, the physician may become "board eligible," and after completion of a certification examination and specialty requirements he or she may become "board certified." Board certification signifies to the lay public that the physician is a recognized specialist in that field.

One may pursue an additional 1- to 2-year specialty education titled fellowship training. This training further refines the physician as an expert in a more specialized field of medical expertise.

The Team Physician

A team physician is primarily responsible for the health and welfare of the individual athletes or athletic teams. The team physician coordinates care with the remainder of the health care team, including athletic trainers, physical therapists, sport psychologists, nutritionists, and other allied health professionals. The responsibilities of a team physician include coordinating preparticipation screening, evaluating injuries and illness, managing injuries on the field of play, developing rehabilitation protocols, establishing return-to-play guidelines, and referring to appropriate specialists outside the team physicians' scope of practice.

Team physicians usually come from two main areas of medical expertise: primary care and orthopedic surgery.

Primary Care Sports Medicine Team Physicians

The American Medical Society for Sports Medicine (AMSSM), founded in 1991, and the American Osteopathic Academy of Sports Medicine (AOASM), founded in 1984, are primary care–based multidisciplinary organizations with the mission to care for the medical and nonsurgical musculoskeletal needs of active individuals.

Many primary care team physicians have completed fellowship training to learn the art and science of sports medicine. Prior to 1999, primary care team physicians who had completed a residency program could sit for the Certificate of Added Qualifications in Sports Medicine exam. Today, a physician must be board certified in family medicine, internal medicine, pediatrics, emergency medicine, or physical medicine and rehabilitation and should have completed a 12- to 24-month accredited primary care sports medicine fellowship to take the certification examination. On successful passing of the examination, one is considered a "sports medicine specialist." Recertification is required both in the primary medical specialty and for the Certificate of Added Qualifications in Sports Medicine on a 7- to 10-year basis. There are two organizations that certify the physicians. They are the American Board of Medical Specialties (ABMS) and the American Osteopathic Association (AOA) Bureau of Osteopathic Specialists. A claim of "board certification" or "certificate of added qualifications" must be accredited by one of these two organizations.

In addition to maintaining specialty certification, the primary care physician must show continuing medical education in sports medicine. Physicians are strongly encouraged to be trained in cardiopulmonary resuscitation (CPR) and advanced cardiac life support and participate in a sports medicine society.

Primary care practitioners who have *not* completed a sports medicine fellowship or who do not have a Certificate of Added Qualifications in Sports Medicine may be qualified to treat athletes depending on their level of experience.

Orthopedic Surgeon Team Physician

The American Board of Physician Specialties certifies candidates who wish to present themselves to the public as qualified orthopedic surgery medical specialists. Board certification includes a written, oral, and clinical (on-site) exam. One must first successfully pass the written portion of the examination before proceeding to the oral exam at the next testing cycle. Trained board-certified examiners, who ask the candidates to present their approach to managing three to five case presentations, conduct the oral examination. After passing the oral exam, two board-certified orthopedic surgeons conduct a clinical (on-site) exam by observing the candidates perform two major orthopedic surgery procedures. They also conduct a medical chart review.

Physicians must recertify on a 7- to 10-year basis. This includes continuing medical education, self-assessment, passing Continuing Medical Education examinations, and passing a 100-question written or computer-based examination. In addition, diplomates must maintain a full and unrestricted medical license.

Orthopedic Sports Medicine Certification

In 2003, the ABMS approved the American Board of Orthopedic Surgery (ABOS) application for subspecialty certification in orthopedic sports medicine. Of the 95 orthopedic sports medicine fellowship programs, 55 are accredited by the Accreditation Council for Graduate Medicine Education. Approximately 200 fellows are trained per year in orthopedic sports medicine. The year 2007 was the first year the sports medicine certification test was offered. After 5 years, one will not be able to sit for the exam unless he or she has completed a certified fellowship.

It is accepted that the training for a general orthopedist plus board certification constitutes more than adequate training. The subspecialty certification was designed to rein in and control the quality of sports medicine fellowships and not preclude anyone from caring for athletes. Any orthopedist may consider himself or herself a sports medicine specialist.

Brent S. E. Rich

See also Careers in Sports Medicine; Running a Sports Medicine Practice; Team Physician

Websites

American Academy of Orthopaedic Surgeons: http://www.aaos.org

American Board of Orthopaedic Surgery: http://www.ABOS.org

American Medical Society for Sports Medicine: http://www.amssm.org

American Osteopathic Society for Sports Medicine: http://www.aossm.org

Cricket, Injuries in

The game of cricket, which originated in England, is played on a grass oval field by two teams. Cricket injuries are documented as far back as 1751, when a prince in England was killed by a cricket ball striking his head.

Game Description

Each team (with 11 players) takes a turn "at bat," during which time two of its players attempt to protect wooden "wickets" placed at the end of the batsman's crease located in the field center. The batsmen are supplied with broad cricket bats made of willow, considerably wider than a baseball bat, with which they attempt to score runs (points) and defend their wicket. Runs are scored by hitting a ball "bowled"

A cricket batsman in action. Ball contact injuries are common while batting, and hand injuries are common while catching the ball.

Source: Can Stock Photo.

toward them using a technique involving a run-up, then projection of the ball with the arm in full elbow extension following an arc that begins with the shoulder in extension and the hand at the side and ends 180° later with the hand at the crest of the arc and the shoulder fully elevated.

The team "in the field" positions its players around the batsmen and attempts to catch balls that are hit toward them. If the ball is successfully hit past the fielders, the batsmen can score runs by running between the two wickets (in effect, the wickets are similar to bases). If the ball is hit hard enough, four runs are scored if the ball leaves the field and six runs if it does so without bouncing. Some of the ways in which the batsmen can be defeated (got "out") are (a) by bowling the ball past them to hit the wickets, (b) catching the ball after it is hit, or (c) throwing the ball back to the wickets while the batsmen are in transit between them after the ball was hit (a "run out"). The ball is made of a core of cork, which is layered with tightly wound string and covered by a leather case with a slightly raised sewn seam, usually red or white; the ball must be caught by the fielder without the use of gloves (except for the wicketkeeper).

Games vary in length, from a "one-day" to a "five-day" series (Test cricket). Cricket is played worldwide, particularly in the countries of the British Commonwealth. The Cricket World Cup conducted by the International Cricket Council is contested every 4 years.

Injuries and Epidemiology

A 2005 consensus recommended that a cricket injury (or "significant" injury for surveillance purposes) is defined as any injury or other medical condition that either (a) prevents a player from being fully available for selection for a major match or (b) during a major match, causes a player to be unable to bat, bowl, or keep wicket when required by either the rules or the team's captain.

Injuries are reported in several contexts. There is little player-to-player contact; however, ball contact injuries are common while batting, and hand injuries are common while catching the ball. Injuries resulting from such impacts are more common during low-level competition or informal participation.

Overuse and improper bowling techniques are thought to be responsible for the high incidence of lumbar spine stress injury, such as spondylolysis. Surveillance of cricket injuries has consistently identified fast bowlers to be the players at greatest risk for such an injury. Such injuries develop gradually and are associated with the cumulative effects of microtrauma to the musculoskeletal system. Fast bowling repetitive microtrauma may be related to a combination of poor technique, poor physical preparation, and biomechanical overload. Studies of fast bowling techniques have reported lower back injuries to be more common with a mixed bowling technique than with a front-on or side-on technique.

Studies of cricket injuries show incidences varying from 0.3 to 33.3 per 1,000 player-hours, with 28% to 72% of cricketers sustaining 1.6 to 1.9 injuries per season. Injuries to the lower limbs vary from 23% to 50% of all injuries. Upper limb injuries account for 20% to 34%, with the site most often injured being the fingers. Back and trunk injuries account for about 18% to 33%; injuries to the head, neck, and face vary from 5% to 25%. An acute injury rate of 57.4 per 1,000 days of cricket played was found in one study in England, with the regional distribution to the head and neck, upper limbs, trunk, and lower limbs being 6%, 29%, 20%, and 45%, respectively. Studies have also found a relatively high incidence of facial injuries in cricket, in comparison with other sports, with the ball's trajectory and bounce off the field during fast bowling to be the major cause of the majority of these injuries.

Among children, cricket injuries comprise 4% of all sports-related injuries, ranking the game as the eighth largest cause of sports-related injuries leading to pediatric emergency department presentations in Australia.

Prevention

Strategies for prevention of injury include mandatory use of helmets for batsmen in youth cricket. Because of the potential severity of the impacts associated with the hard ball, a range of protective equipment has become a common feature of standard cricket equipment.

General strategies that can be used to prevent a wide range of injuries from occurring include good stretching programs before and after play, as well as comprehensive conditioning and technique programs before and during the season.

Cricket is generally a summer sport; thus, with exposure to the sun and high temperatures comes an increased risk of skin cancer, dehydration, heat exhaustion, and heat stroke. For Test cricket, cricketers are required to wear white shirts and pants ("trousers"), while a hat is optional. The white color reflects heat to a greater extent than darker-colored clothes. The eyes and skin are also given additional protection from the sun. Sun block gives additional protection to the exposed body parts. More often now, professional cricket is played at night under floodlights.

Hamish A. Kerr

See also Hand and Finger Injuries; Protective Equipment in Sports; Spondylolysis and Spondylolisthesis

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Cross-Training

Athletes spend endless hours participating in their sport of choice. But at times, they may choose to cross-train. By definition, *cross-training* means an athlete participates in a different form of exercise than his or her usual sport. Therefore, it is a form of exercise that is not necessarily sport specific. It has been classically used to refer to aerobic forms of exercise only. This entry provides an overview of the basic concepts and discusses the potential benefits of cross-training for athletes.

Common forms of exercise that improve cardiovascular function include running, biking (stationary or road), using the elliptical trainer, swimming, and deepwater running. The main concept behind cross-training is to pick a form of exercise that stresses a body part that is different from the athlete's primary sport of choice. Therefore, if an athlete is involved in a predominantly weight-bearing sport such as running, he or she would likely cross-train on a bike or in a pool. Athletes involved in sports that emphasize overhead activity, such as tennis, volleyball, baseball, and softball, may benefit from choosing a form of cross-training that emphasizes lower body fitness. This would include all the above forms with the exception of swimming. These concepts can be applied for basic fitness training as well as for rehabilitating an athlete who is recovering from either an acute or a chronic injury.

Athletes may choose to cross-train for a variety of reasons. One of the most common reasons is to decrease boredom. Individuals frequently get bored participating in the same form of exercise day in and day out. By mixing up the routine with a different form of exercise, they may be more compliant with their workout regimen. The variety can help keep athletes motivated and engaged in their program, which may eventually lead to improved fitness.

Another common reason for cross-training is injury prevention. When athletes are involved in training on a regular basis, they are at increased risk of suffering an overuse injury. For instance, runners are at high risk of suffering stress fractures in the weight-bearing bones, such as the metatarsals, tibia, and femur. Similarly, athletes who perform repetitive overhead activity, such as swimmers, may develop chronic shoulder pain. These injuries can limit an individual's ability to participate in sport-specific training. Cross-training can be substituted for sport-specific training before an injury happens. This may help limit the athletes' risk of overuse injury, simply by decreasing their time spent training in their primary sport. Therefore, some people view cross-training as a possible preventive training technique.

Cross-training is most commonly relied on as a way of conditioning individuals when they are unable to train in their usual sport of choice. This situation typically arises when an individual is injured. For instance, if a runner has suffered a lower extremity stress fracture and is unable to run, it may be safe for him or her to swim or even run in deepwater, helping to minimize the impact. Likewise, an athlete who is recovering from an acute injury, such as a football player with a dislocated shoulder, may be unable to return to the football field, but he or she can likely ride a stationary bike and even progress to running when he or she is more comfortable. This allows the athletes the ability to maintain their cardiovascular fitness while they are unable to participate in sport-specific forms of training. Cross-training also allows injured athletes to remain actively involved in their rehabilitation process. Athletes who are able to stay active through cross-training may have less anxiety about their injury, feel less depressed about missing time away from their sports, and feel better prepared to return to competition when they are physically able to.

The actual training benefits of cross-training are variable. For individuals who are unfit or moderately fit, cross-training can help improve their cardiovascular base. It can also help these athletes diversify their sports skills and gain skills that they may not have gained in their primary sport of choice. For elite athletes, there is very little cardiovascular gain that can occur from cross-training. These individuals typically are already maximally conditioned, and cross-training will not improve their fitness. Some researchers believe that the time away from his or her primary sport may even harm an elite athlete's ability to perform sport-specific skills.

Overall, sport-specific training appears to provide greater gains in both cardiovascular fitness and sport-specific skills for athletes. Still, cross-training can play an important role for athletes, particularly for unfit individuals or those who are rehabilitating from an injury.

Susannah Briskin

See also Aerobic Endurance; Conditioning; Stress Fractures

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Crutches, How to Use

Crutches have long been used as a support device for individuals with lower extremity injury. They serve a vital function for the athlete seeking to maintain mobility and fitness while not bearing weight. Proper and efficient use of crutches depends on careful fit and comprehensive instruction in appropriate gait sequence.

Function

Crutches are within the class of medical tools called *orthotics* (or orthoses). They are commonly prescribed after an acute orthopedic injury to the lower extremity. Often with such injury, the patient is either unable or specifically instructed not to bear weight. Crutches serve as a support onto which weight is shifted, thus helping relieve discomfort and reduce recovery time from injury. Crutches are most essential as an assistive device for mobility purposes, also referred to as an ambulatory aid.

The primary function of the crutch is to reduce weight load on the injured leg while also enabling adequate balance and stability during ambulation. Serving as a broad-based extension of the upper extremities, crutches shift the force of upright movement from the legs to the upper body. Proper use of crutches as an ambulatory aid requires sufficient upper limb strength, coordination, and hand function.

Types

There are primarily two types of crutches currently in use. The underarm (or axillary) crutch, the type most commonly prescribed in the United States, is used most often by patients with acute injury or temporary disability. The forearm (or nonaxillary) crutch is used in the United States almost exclusively by patients with permanent lower extremity disability.

The underarm crutch has the primary advantage of allowing transfer of 80% of the user's body weight. By providing support from the axilla to the floor, underarm crutches allow for better trunk control. In contrast, forearm crutches allow transfer of only 40% to 50% of the user's body weight and require good trunk control to operate safely.

Proper Fit

The standard underarm crutch is adjustable for length. There are several key components of an underarm crutch, designed to enhance safety and comfort. The crutch tips, in contact with the floor, must be made of rubber and be at least 1.5 inches (in.) (3.81 centimeters [cm]) in diameter. The crutch tip can be fitted with a retractable metal spike for use on ice. The handgrips are ideally thickly padded with sponge rubber to reduce friction and blunt the pressure on the palms. The underarm component is typically fitted with a sponge rubber pad, but it must be stressed that the axillary crutch is not designed to be tucked into the underarm and rested on for body support. This action increases risk of injury to the axillary nerves and blood vessels.

To optimize dynamic function while simultaneously minimizing risk for complication, crutches must be properly fitted via a measurement prescription. For underarm crutches, measurement should proceed as follows: With the patient standing, determine the crutch length by measuring the distance from a point 3 in. (7.62 cm) below the armpit to a point 6 in. (15.24 cm) lateral to the fifth toe. With the crutch now set at proper length, place the tip 3 in. (7.62 cm) lateral to the foot to determine the optimal hand piece location. The hand should rest at a level that allows for 30° of elbow flexion while the wrist is in maximal extension and the fingers are flexed into a fist. To confirm proper fit, the patient should be able to raise his or her body 1 to 2 in. (2.54–5.08 cm) with complete elbow extension. If the patient is in a supine position, the measurements will not be accurate.

Gait Sequences

There are different gait sequences available to the patient requiring crutches. The appropriate sequence is determined in large part by the nature of the injury or disability in conjunction with the patient's capabilities. Some gait sequences require considerable upper body strength and energy expenditure, whereas others require exceptional balance and coordination. In the case of an athlete with acute injury to the lower extremity, two gait sequences are commonly employed. The "three-point" or non–weight-bearing gait entails a first step of putting forward both crutches and the injured lower limb (the three points), then a second step of bringing the unaffected limb up to and even with the crutches. The more difficult "swing-through" gait entails a first step of planting both crutches forward, followed by a second step of swinging both lower limbs through and past the crutches. This technique allows the patient to move faster than with a normal walking gait. To perform this sequence safely and effectively requires strong, functional abdominal and upper limb musculature and good trunk balance.

How to Use

These gait sequences are ideally taught by an experienced physical therapist prior to hospital discharge. The majority of patients, however, are instructed in the non–weight-bearing gait in an office setting. The basic principles for safe and effective performance of this sequence are as follows: To begin walking, lean forward slightly, and place the crutches about 1 foot (0.3048 meters) in front. Shift your weight to arms/crutches, and sway forward. Swing the good leg forward between the crutches, and plant it on the ground. Shift the weight to the good leg, and repeat the sequence. Remember to keep your eyes focused on where you are walking and not on your feet. Keep your steps small, and never support yourself on your armpits.

To safely sit with crutches, the following is recommended: Back up to the seat. With both crutches in one hand, place the other hand on the seat, and lower yourself down. To stand from a seated position, first move to the front edge of the seat. Hold both crutches in the hand on the injured leg side, put your weight on the good leg, and push with your arms to stand. Crutch use on stairs is best avoided whenever possible given the inherent risk of falling, particularly on descent.

Complications

Underarm crutches set at too long a length or used incorrectly can lead to significant medical complications. It has been determined that excessive weight bearing on the axillary bar can lead to a seven-fold increase in force on the axilla. Complications that may result include compressive injury to the nerve complex (the brachial plexus) located in the underarm, otherwise known as *crutch palsy*. The affected individual typically presents with grossly evident muscle weakness in both arms. With proper treatment, most patients with crutch palsy fully recover in 8 to 12 weeks. A less common complication is crutch-induced axillary artery injury. With this entity, blood vessel injury leads to decreased blood flow to the arm. These complications are largely preventable by ensuring correct length and proper use of underarm crutches. The advent of spring-loaded axillary crutches, which may alter the way loads are transmitted to the body during crutch gait, may reduce the potential for complications.

Adam Eugene Perrin

See also Orthotics

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Cryotherapy

Immediate application of cryotherapy is one of the essential modalities in the treatment of an acute injury. *Cryotherapy* is the therapeutic use of cold to control inflammation and edema, decrease pain, reduce spasticity, and facilitate movement. Tissue cooling is achieved through the application of cold through the skin. The application of cold produces a sensation of intense cold followed by burning, aching, decreased pain, and numbness.

Indications for cryotherapy include acute injury or inflammation, acute or chronic pain due to muscle spasm, edema/swelling, spasticity accompanying a central nervous system disorder, painful limitation of motion secondary to immobilization, and first-degree burns.

Contraindications include cold hypersensitivity, circulatory compromise, history of frostbite, leukemia, and/or systemic lupus. Precautions must be taken in the case of open wounds, hypertension, poor sensation, aversion to cold, poor mentation, prolonged application over a superficial nerve, and patients who are very young or very old.

Adverse reactions can include tissue death, frostbite, nerve damage, and unwanted opening of the blood vessels (yielding increasing blood flow).

Cold Packs

A cold pack is a superficial physical agent that reduces tissue temperature by means of conduction. Cold packs are typically composed of an outer vinyl pouch filled with a silica gel mixture that is kept between 0 °C and 5 °C. This method is used to achieve constriction of the blood vessels, decrease tissue metabolism, decrease pain threshold, reduce muscle spasm, temporarily decrease spasticity, and decrease tissue elasticity.

A protective layer should be placed between the cold pack and the skin. The layer can be either dry or damp. Place the pack on the area to be treated, and secure it well. The skin should be checked after 10 to 15 minutes for any signs of adverse effects, such as a rash or bluish/whitish coloring of the skin. Following 20 minutes of cold, the skin may be red or dark pink. Application of the cold pack may be repeated every 1 to 2 hours to control pain and inflammation.

Ice Massage

Ice massage is a convenient and easy example of cryotherapy. An ice cup (a paper cup filled with water that has been frozen) is used for the massage. Move the ice over the area to be massaged in small, overlapping circles. Ice massage can be done for 3 to 5 minutes or until numbness is experienced. The treatment area should be inspected for any signs of adverse reactions.

Contrast Bath

A contrast bath is a method applied by alternately immersing an area in warm or hot water, followed by cool or cold water. This method is used to increase superficial circulation, decrease pain, reduce muscle spasm, relieve joint pain and stiffness, decrease swelling, and increase tissue metabolism. Due to the circulatory effect of alternating opening and closing of the blood vessels, a pumping effect is achieved. Contrast bath is often used for edema and inflammation control. Indications for contrast bath are sprains, strains, tendinitis, and hypersensitivity. Contraindications are recent skin grafts, infection, bleeding, or decreased thermal sensation.

Two containers of water are placed adjacent to each other, one filled with warm water (38–44 °C) and the other filled with cool water (10–18 °C). The area to be treated is placed in the warm water first for 3 to 4 minutes. Then the area is immediately placed into the cool water for 1 minute. This sequence is repeated for up to 30 minutes. Recommendations for ending with cold or hot may be found equally in the literature, but there is no conclusive evidence to support either hot or cold as having superior effectiveness.

Shanan Haggerty

See also Hydrotherapy and Aquatic Therapy; Physical and Occupational Therapist; Principles of Rehabilitation and Physical Therapy

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Cyst, Baker

A *Baker cyst,* synonymous with a popliteal or synovial cyst, is an outpouching of fluid located at the back of the knee. Each of the three terms illustrates a different aspect of this condition or refers to its history. Dr. William M. Baker was one of the first physicians to describe this cystic structure. His publication on the formation of synovial cysts dates back to 1877. The term *synovial cyst* is used because the cystic structure often fills with synovial or joint fluid to produce its characteristic bulge. The term popliteal refers, in anatomy, to the area at the back of the knee where this cyst is found. For consistency, the term *Baker cyst* will be used for the remainder of this entry, but it is important to consider these other terms when conducting further research or communicating with health care providers. This entry will outline the symptoms, diagnosis, complications, and treatment of Baker cysts.

Symptoms

Although a Baker cyst is generally not a dangerous condition, it can impair an athlete's ability to train. This cyst, characterized by excess swelling in the back of the knee, presents as a smooth, compressible bulge and has the feeling of a fluid-filled sac. The cyst will be more prominent with the extension of the knee. Cysts will frequently soften with flexion of the knee to 45° and may sometimes disappear. The area of swelling can be quite painful, especially if the cyst ruptures. In addition, larger, painful cysts can limit the range of motion of the knee, thus limiting the athlete's ability to participate in training. Although the medical community generally views this condition as benign, it can be debilitating to active individuals.

Baker cysts are found in both children and adults; however, their prevalence tends to increase with age. There are two peaks in incidence, one occurring between ages 4 and 7, the second between ages 35 and 70. Interestingly, younger patients rarely have any associated joint problems, while older patients often have a variety of conditions affecting the knee. The presence of a Baker cyst may actually be an indication that there are other mechanical or inflammatory problems with the knee. Meniscal tears, arthritis, and ligament damage are all conditions that have been associated with Baker cysts in adults. Athletes who develop a cyst after trauma to the knee should be wary of possible soft tissue damage within the joint.

While there are several injuries that can lead to the development of a Baker cyst, there are also separate conditions that may imitate it, such as deep vein thrombosis (blood clots), aneurysms, muscle strains, and soft tissue tumors. Some of these conditions, especially blood clots, are more serious and may require prompt evaluation by a physician.

Anatomy and Pathophysiology

To understand how a Baker cyst is formed, it is important to understand the anatomy of the knee. The knee is a compound joint involving three bones: the tibia, the femur, and the patella, otherwise known as the kneecap. The medial and lateral menisci are structures composed of cartilage that cushion the impact between the two heads of the femur and the tibia. As noted earlier, injuries of the menisci can be related to the development of a Baker cyst.

Generally, the back of an extended knee, commonly referred to as the popliteal fossa, is soft and flat. The popliteal fossa is bordered by several muscle tendons, including the hamstrings and the gastrocnemius, commonly referred to as the calf. Important structures such as the popliteal artery and vein, as well as the tibial nerve, run through this space.

The actual knee joint is in front of the popliteal fossa. The joint is completely enclosed in a fibrous material referred to as the joint capsule, which contains the synovial fluid of the knee. Synovial, or joint, fluid is secreted by the cells within the capsule and is essential for lubrication of the knee, which decreases friction at the joint. The leaking of this fluid is one mechanism by which a Baker cyst is formed.

The most widely discussed mechanism for the formation of a Baker cyst is the swelling of a bursa, which results from the connection of the bursa with the joint space. Bursae are fluid-filled sacs that cushion areas of increased friction in the body. There are several primary bursae located around the popliteal fossa. Although any of the bursae in this area may swell, the gastrocnemius-semimembranosus bursa is most commonly related to the development of a Baker cyst. This bursa is located on the medial, or inner, portion of the back of the knee.

When an athlete experiences trauma to the knee, resulting in damage to one of the inner structures, an effusion often forms. As the amount of fluid increases, so does the pressure inside the joint capsule. Under normal circumstances, there is no passage of fluid from the knee joint to the bursa. As the fluid in the knee builds, however, it can sometimes leak into the adjacent bursa and create a cyst. Notably, there are instances when athletes develop Baker cysts and underlying problems with the knee are never detected. There have also been cases of Baker cysts that form as a result of swelling of the bursa, with no communication to the joint. Occasionally, the joint capsule itself can swell to the point where it is responsible for the formation of a Baker cyst.

Diagnosis

Although these cysts can be diagnosed by physical examination alone, imaging may help distinguish them from other, more serious problems. Several techniques, including ultrasound and magnetic resonance imaging (MRI), have been used for examination. Ultrasound is extremely useful as it allows the physician not only to visualize the cyst but also to distinguish it from a deep vein thrombosis or an aneurysm. An MRI scan is generally not necessary for diagnosis; it can be extremely useful though in visualizing damaged soft tissue, such as meniscal tears or ligamentous injuries. Although plain X-rays cannot clearly visualize the cyst, they may be useful in identifying underlying arthritis.

Complications

Rupture is the major complication of a Baker cyst and can sometimes be the presenting sign. Rupture can be very painful and lead to additional swelling of the back of the calf. Because of the additional swelling, ruptures mimic the signs of a blood clot more closely than an intact cyst. The *British Medical Journal* reported just such a case in a 25-year-old rugby player. The man, a healthy athlete who did not report any previous knee injury, was admitted to the hospital 3 hours after playing in a rugby game. During the second half of the game, he experienced pain in the back of his left calf. On evaluation, his knee and the back of his calf were swollen, and the back of his knee was very tender. An imaging study demonstrated that he had a ruptured Baker cyst. The patient rested for 48 hours and then resumed normal activities but did not return to athletics until 2 months later. Generally, ruptured cysts may be treated with analgesics, rest, and elevation.

Treatment

Treatment of a Baker cyst varies with the degree of impairment an athlete experiences. Asymptomatic cysts require no treatment. There are several reports of improvement of Baker cysts after steroid injections into the knee joint. The injected steroid limits inflammation at the joint. Notably, these injections are not generally successful if the cyst does not communicate with the joint space. If underlying joint or soft tissue disease is identified, treatment of these conditions may result in resolution of the cyst. Although surgical excision is not a definitive cure, patients with bothersome cysts refractory to conservative management may consult a surgeon regarding cyst excision.

Baker cysts are common findings in athletes, particularly those with associated knee injuries. Although these cysts are benign, they can mimic other, more serious conditions, and for this reason, they require evaluation. Athletes whose performance is impaired by a Baker cyst can often achieve alleviation of symptoms with conservative management, which has few complications.

Jeffrey Manning

See also Bursitis; Joint Injection; Knee Bursitis; Meniscus Injuries

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Cyst, Ganglion

A *ganglion cyst* is a small, fluid-filled sac (usually less than 2 centimeters) that is located near a joint capsule or tendon sheath (the covering surrounding a tendon). It is thought to arise from a herniation of synovial (joint) tissue from the joint or tendon sheath. Experts do not know the exact cause of ganglions but believe that they may be associated with some type of trauma or tissue irritation. Overuse or repetitive motion may predispose a person to the formation of a ganglion cyst. Ganglion cysts are often found on the back of the wrist and appear as firm, pea-sized nodules (see Figure 1).

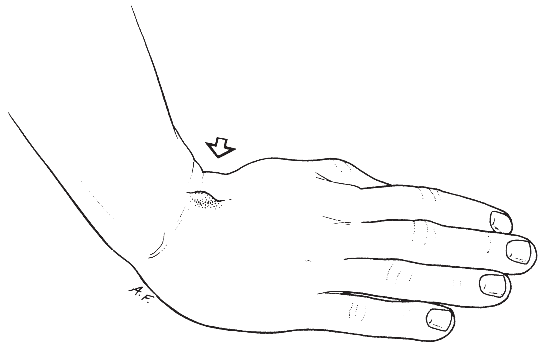

Figure 1 Common Location for a Ganglion Cyst

Ganglion cysts account for approximately 60% of the soft tissue tumors affecting the hand and wrist. When found at the fingertip, just below the cuticle, they are called *mucoid cysts*. The cyst is composed of a thick, jelly-like material. They are not cancerous. Ganglions affect people of all ages. They are common in adults between the ages of 15 and 40 and occur in women three times as often as in men. Ganglion cysts may occur in children as well (see image, page 345). Treatment consists of both nonsurgical and surgical options.

Anatomy

Since ganglia most commonly affect the hand and wrist, this anatomic review will focus on that region. The hand is composed of 14 bones, and the wrist is composed of eight bones. Special hinges called *joints* separate the bones. These joints contain fluid that lubricates them, allowing for smooth motion. Muscle contraction creates the movement of the bones. The muscles are attached to the bones by tendons. When the muscles in the forearm contract, the tendon is pulled, and the finger bends. A special tube containing lubricating fluid covers some of the tendons. The lubricating fluid allows for smooth and painless movement. The tendons and their special tubing are held in place by a specialized covering called a *sheath*. The joints and tendons are common areas where ganglia can develop.

A ganglion cyst in a child

Source: Photo courtesy of the authors.

Symptoms

Usually, ganglions are small, painless masses that may change in size. Some ganglia, however, may cause pain because they put pressure on the surrounding nerves. This pressure may also cause a tingling sensation in the hand. The pain is usually described as an ache and is made worse by repetitive activity. Larger ganglia may cause limitations in the range of motion. When the cyst is connected to a tendon in the hand, a sense of weakness may occur. Some ganglions may be cosmetically unappealing.

Diagnosis

A ganglion can usually be diagnosed by its appearance and location. An experienced health care professional will ask questions relating to the duration of the mass, whether it is painful, and whether it has changed in size, to aid in making the diagnosis. He or she may examine the mass and shine a light beside it. If the light shines through it, it is likely a ganglion. This process is called *transillumination*. An ultrasound can be helpful if the diagnosis is uncertain or if there is concern that the mass is caused by another tumor or a blood vessel. In some cases, ganglions may be small and undetectable on examination (occult), but they can still cause pain. In these cases, magnetic resonance imaging (MRI) can help identify the cyst and differentiate other types of masses.

Treatment

A traditional treatment for a ganglion cyst was to hit it with a large book, such as a bible, since the cyst can burst when struck. This form of treatment is no longer recommended due to the possibility of causing other damage to the hand or wrist. Today, there are alternative options for treatment, both surgical and nonsurgical.

Nonsurgical Treatment

If the cyst is not painful, treatment may consist of nothing more than watching and waiting, as the ganglion may resolve on its own. Avoiding repetitive motion may help reduce the symptoms. This may be accomplished by wearing a brace or splint to immobilize the wrist. Massaging may reduce the fluid within the ganglion. If the cyst is large or painful, the fluid may be drained with a needle and syringe. This is called *aspiration*. Unfortunately, the cyst wall and the stalk are still present and can refill with fluid. The recurrence rate of ganglion cysts after aspiration is as high as 30% to 60%. Sometimes, an injection of a corticosteroid may follow aspiration in an effort to avoid recurrence of the cyst. However, the efficacy of the corticosteroid injection is questionable. It is not found to offer any additional benefit over aspiration alone and can cause skin discoloration as well as thinning of the skin and underlying tissue.

Surgical Treatment

Surgery may be recommended if the other treatments fail and the cyst is painful, limiting normal function, or causing numbness and tingling. The recurrence rate for ganglion cysts after surgery is 5% to 15%. This surgery is usually performed as an outpatient operation, and the patient goes home on the same day of the surgery. The operation is done through a small skin incision after the area is anesthetized. The surgery includes the removal of the cyst, along with a small amount of surrounding tissue. Normal activity can usually resume within a few weeks after surgery.

Victor M. Vargas and Katherine M. Walker

See also Hand and Finger Injuries; Hand and Finger Injuries, Surgery for; Joint Injections

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D

Dance Injuries and Dance Medicine

Dance medicine is the much younger and less well-endowed stepsister of sports medicine. As a clinical specialty, its origins can be traced back to the early 1980s, when a few pioneering orthopedic surgeons became associated with major ballet companies, mainly in the English-speaking world. More widespread interaction has developed steadily but slowly, restricted by a number of factors. Relative to athletes, for example, dancers are a small and, for the most part, impecunious population; hence, there is little incentive for doctors to seek them out as patients. From the dancer's point of view, doctors have traditionally been seen to be ill informed where the demands of their discipline are concerned, all too ready to require of them untenable lapses of time away from dance and prohibitively expensive. At least, until recently dancers have tended to seek out instead what they consider to be the quick-fix services of adjunctive medicine practitioners, such as chiropractors.

Several developments have begun to alter this situation. For one, various forms of health insurance—including, but by no means limited to, workers' compensation—have become available to an ever-increasing number of dancers at all levels of the field. Perhaps more important is the role of physical therapists, broadly defined as liaisons for dancers with the world of medicine. Because these people tend to be readily available and use therapeutic modalities that are particularly germane to the treatment and rehabilitation of dance injuries, they have been especially effective in making standard medical care more acceptable and available to dancers.

The other part of the foundation on which dance medicine rests—scholarly research—was also laid down in the 1980s. Indeed, although there had been what might be described as a smattering of articles previously distributed through the periodical literature, one publishing event can reasonably be identified as having set the whole enterprise in motion. In conjunction with the summer Olympic Games of 1984, a "Scientific Congress" was held in Eugene, Oregon, one aspect of which was devoted to dance medicine. This gave rise to the book *The Dancer as Athlete,* edited by Caroline G. Shell, which was essentially a compilation of the papers presented at the Congress. In short order, this was followed by three other edited books of the same nature—that is, collections of articles intended cumulatively to provide an overview of the major concerns of the field—*Dance Medicine: A Comprehensive Guide* (Allan J. Ryan and Robert E. Stevens, 1987), *Dancing Longer, Dancing Stronger* (Andrew Watkins and Priscilla Clarkson, 1990), and *Preventing Dance Injuries* (Ruth L. Solomon, John L. Solomon, and Sandra C. Minton, 1990, 2005). These remain the classic dance medicine texts.

There is now a *Dance Medicine and Science Bibliography* that, in its fourth edition (2007), lists 2,927 entries indexed under 600 subject headings, with an author index as a comprehensive guide to the 3,600 authors whose names appear in the

Bibliography. There is also the *Journal of Dance Medicine and Science,* a quarterly devoted to publishing the most current and germane research in the field. These publications are distributed under the auspices of an organization, the International Association for Dance Medicine and Science (IADMS), that, since it was founded in 1990, has played a crucial role in organizing and promoting the interests of the field worldwide. IADMS was created by an international group of dance medicine practitioners, dance educators, dance scientists, and dancers. Membership is drawn equally from the medical and dance professions and has grown from an initial 48 members in 1991 to more than 900 at present, representing 35 countries.

As should be apparent from the linking of "medicine" and "science" in so much of what has already been said, it is virtually impossible to separate these two aspects of the subject at hand. Dance medicine and science is thoroughly interdisciplinary in nature, and what the science component brings to the table is a sweeping panorama of perspectives that qualify and enhance the medical focus in innumerable ways. Among the most notable contributing disciplines are the following: anatomy/physiology, kinesiology, biomechanics, movement analysis, psychology, nutrition/diet, somatics, body therapies, physical therapy, dance therapy, and dance education.

Dance Injuries

Not surprisingly for such a young field, the early history of dance medicine, especially as it pertains to the injuries that most specifically distinguish dancers as a medical population, is marked by fits and starts, hits and misses. The epidemiology of dance injuries is an excellent case in point. Early researchers were quick to tackle this issue, but with no history and few lines of communication to draw on, they tended to go their separate ways. Basic questions such as how to define "injury," how most accurately to gather injury-related information, and how best to correlate injuries with other variables remain somewhat in doubt even to this day. Hence, it is generally no easy matter to compare the results of one study with the results of any another, and the deviations between studies are often alarmingly large. Nonetheless, certain basic facts are by now well established.

First, there is no doubt that the vast majority of dance injuries occur below the waist. Although percentages of the whole will vary from study to study, or in the anecdotal observations of clinicians drawn from their practices, the most common sites of dance injuries are the foot/ankle, lower back, hip, and knee, almost unequivocally in that order. Second, granted that strains/sprains (especially of the back and ankle) are very common occurrences, most dance injuries that result in significant time away from dance are microtraumatic rather than traumatic in their etiology. This relates directly to the concept of "overuse," which is very commonly used in the field, especially when discussing the "risk factors" that are said to perpetuate dance injuries.

It is well understood that dancers are exposed, in pursuing their daily regimen, to certain potentially injurious factors. The most obvious of these are said to be "external," or "environmental," in nature. This refers to matters such as practicing and performing on hard or uneven floors, sometimes in venues that are insufficiently heated, and in footwear that provides less than adequate protection. There are also the problems that dancers impose on themselves by failing to warm-up or cooldown appropriately or that result from faulty conditioning or diet. More subtle, but also on balance more important, are the so-called internal risk factors. These all relate to one basic idea—namely, that any asymmetry or anomaly in the dancer's anatomy is a potential source of injury when it comes into conflict with the demands of the discipline. This is, again, the concept of "overuse"—that is, at the point where the dancer's anatomic weakness is exploited day after day by the need to perform the same movements endlessly, the body is likely to break down.

That these principles are indeed at work in dance is clearly illustrated by the nature of the injuries that dance medicine practitioners most often encounter. This could be demonstrated with reference to any of the common sites of dance injuries previously enumerated, but space allows for just one example. A recent article by John J. Kennedy and Christopher W. Hodgkins, titled "Foot and Ankle Injuries in Dancers," begins with the following statement: "Much of a dancer's ability is reliant on favorable anatomy, strength and flexibility. Their foot mechanics, training and performing techniques are unique and thus they present with particular injury patterns." The article goes on to discuss the following conditions: bunions, hallux rigidus, sesamoiditis, sesamoid bursitis, Joplin neuroma, nerve entrapment, metatarsal-phalangeal instability, Freiberg infraction, fifth metatarsal fractures, ankle sprains, posterior impingement syndrome, os trigonum, flexor hallucis longus tendinitis, Achilles tendinitis, heel spurs, plantar fasciitis, plantar calcaneal bursitis, and Baxter nerve neuropraxia. This list is noteworthy both for its inclusiveness (dancers obviously are vulnerable to many different foot and ankle injuries) and its homogeneity; almost without exception, these are injuries that result from repetitive microtrauma.

Conclusion

As it progresses well into its third decade as a recognizable discipline, dance medicine and science is positively influencing the dance community in general and, most specifically, the daily lives of dancers in numerous ways. Its greatest achievement may well lie in the rapprochement it has begun to effect between dancers and the medical personnel who are equipped to deal with their injuries. This has much to do with an increased willingness on the part of dancers to accept the fact that they are, albeit in a very special sense, athletes. Movement in that direction has the potential of opening to them all the established resources of sports medicine. Such an alliance between these two siblings should over time work very much to the advantage of dance medicine and science.

Ruth L. Solomon and John L. Solomon

See also Achilles Tendinitis; Ankle Sprain; Bunions; Foot and Ankle Injuries, Surgery for; Plantar Fasciitis and Heel Spurs; Posterior Impingement Syndrome; Sesamoiditis

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Deep Heat: Ultrasound, Diathermy

Deep heat is provided by therapeutic modalities that are capable of increasing the temperature of the deeper tissues and structures. Physical therapists traditionally use these modalities as a component of a comprehensive treatment program to improve impairments and functional limitations that may be caused by an injury.

The physiological and clinical effects of deep heating agents are generally the same as those produced by superficial heating agents—that is, they control pain, decrease joint stiffness, increase circulation, and promote healing.

Ultrasound

Therapeutic ultrasound (US) is produced by a transducer that converts electrical energy into sound energy. On the electromagnetic spectrum, US waves occupy frequencies greater than 20,000 hertz (Hz)—for therapeutic US, usually 0.7 to 3.3 MHz. (Humans hear sound with frequencies of 16–20,000 Hz.) Sound waves can be produced as a continuous wave or as a pulsed wave. These waves can penetrate deep into tissues, perhaps as far as 5 centimeters. Clinically, the effects resulting from the interaction of US with tissue can be grouped into two categories: (1) thermal US elevates tissue temperature—in subacute and chronic conditions, thermal US can be used to treat muscle spasms, joint stiffness, and pain—and (2) nonthermal US changes the cellular processes that enhance tissue healing—in acute cases, nonthermal US can be used to decrease swelling and pain in conditions such as bursitis or tendinitis. There is some preliminary research to indicate that low-intensity pulsed US may be helpful in promoting the healing of fractures. Standard contraindications/precautions for the use of US include malignancy, pregnancy, cardiac pacemaker, thrombophlebitis, acute inflammation, open growth plates in children, and fractures (for high-intensity US). Therapeutic US should not be confused with diagnostic US, which is used, for example, over the uterus in pregnancy.

Shortwave Diathermy

Shortwave diathermy (SWD), a modality used less commonly today than in the past, uses electromagnetic energy to generate heat that can affect a larger area of the body and penetrate deeper into tissues (continuous SWD with high pulse frequencies). It also produces nonthermal effects in the treatment of acute and chronic infections to decrease pain and edema (pulsed SWD with low pulse frequencies). SWD may cause soft tissue burns if not used at correct doses. It has been suggested that the therapist delivering the treatment may be susceptible to an electromagnetic field and be exposed to radiation. For these reasons, other modalities are preferred by therapists and athletes. Standard contraindications/precautions for the use of thermal SWD include metal implants, malignancy, pregnancy, open growth plates in children, and obesity. Those for the use of nonthermal SWD include pregnancy, metal implants, open growth plates, pacemakers, and the treatment of deep tissues (internal organs).

Penelope Sullivan, Joan Widell, and Michelina Cassella

See also Principles of Rehabilitation and Physical Therapy

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Dehydration

Dehydration means an abnormal depletion of body fluids, which occurs when fluid intake does not match body fluid loss, giving rise to imbalances. Dehydration may occur frequently during exercise, impairing performance and exposing athletes to risks that could be serious. The term *euhydration* refers to normal body water content, and the terms *hypohydration* and *hyperhydration* are related to deficits and excesses in body water content, respectively. This entry focuses on the following topics: (a) fluid intake and fluid loss mechanisms, (b) dehydration symptoms, (c) the relationship between dehydration and heat illnesses, (d) dehydration-influencing factors, and (e) prevention measures against dehydration in sports.

Fluid Intake and Fluid Loss

Fluid intake occurs principally during drinking (about 60%) and eating (about 30%); 10% of the fluid intake results from the metabolic processes within the body.

Fluid loss occurs through excretion from the kidneys (which in resting conditions amounts to approximately 60% of the total fluid loss), excretion from the large intestine (approximately 5%), evaporation of water from the respiratory tract, and sweat secretion (about 35%).

Sweat components are principally water and electrolytes; these help in regulating nerve and muscle function and in maintaining acid-base balance and fluid balance.

Fluid loss rates can vary greatly depending on many factors. These include environmental factors (e.g., radiant heat from surfaces such as black asphalt), climatic conditions (e.g., temperature, humidity, solar load, and wind velocity), and other factors concerning the specific characteristics of each individual (e.g., gender, age, health status, training status, psychological features, clothing and equipment, intensity of physical activity, degree of heat acclimatization, and exercise-induced metabolic body heat production). Moreover, all these factors may interact synergistically, stressing the physiological systems even more. However, even in cool conditions, sweat loss can be considerable: The highest sweat rate reported in the literature, measured in an athlete during his preparation for a marathon, is 3.7 liters/hour.

In fact, excessive fluid loss can be fatal, because water is essential for human life: It constitutes nearly 60% of body weight and about 72% of lean body mass and forms the basis for all body fluids, among them blood. As water is the principal constituent of the body, even a 9% to 12% fluid loss can have serious consequences.

The body fluids have vital functions: They contribute in the transportation and absorption of nutrients, allow muscle contraction, and help in eliminating waste. For this reason, it is essential to maintain the correct parameters of these fluids, especially blood parameters, such as blood volume and blood pressure. In effect, the body tries to defend blood volume as much as possible in hypohydration situations: Water passes from inside the cells to the bloodstream. Through this fluid exchange, dehydration causes a redistribution of body water, which largely derives from depletion of the water content of muscles and skin. Thus, depletion of body levels of fluid can significantly stress the body, impairing physical performance.

Consequently, dehydration should be limited and, better still, prevented. To prevent dangerous dehydration, the brain stimulates the thirst center, inducing the hypohydrating individual to drink more fluids. Yet if fluid intake cannot balance fluid loss, dehydration becomes more severe. The body tissues start to dry out, to such an extent that cells may shrivel and malfunction.

Symptoms of dehydration include thirst; dry mouth, skin, and mucous membranes; decreased sweating and urine output; headache; muscle weakness; excessive fatigue and tiredness; dizziness; cramps; fever; low blood pressure; and in the most severe cases, damage to the internal organs, confusion, delirium, or even unconsciousness.

Dehydration and Heat Illnesses

Several researchers (among them Jay Hoffman, Julian Bailes, and Vincent Miele) believe that many symptoms of dehydration show a connection between dehydration and heat illnesses. Heat illnesses include heat cramps (painful involuntary spasmodic muscular contractions), heat syncope (loss of consciousness because of a temporary decrease in the blood supply to the brain), heat exhaustion (great weakness and elevation of pulse rate and temperature), and heat stroke, a life-threatening condition in which the body temperature may rise to 110 °F (43 °C) and many organs, such as the heart, kidneys, and even the brain, may suffer damage. A euhydrated individual can cool his or her body through the evaporation of the sweat secreted by the sweat glands situated all over the body. On the contrary, these researchers claim, a dehydrated person has limited ability to regulate his or her temperature by sweating and/or by skin blood flow. In this way, they maintain, dehydration may cause heat illnesses. Therefore, these researchers warn athletes against the synergistic interaction that may occur between heat and exercise-induced dehydration. To minimize the risks of thermal injuries, they encourage athletes to adopt adequate preventive measures, recommending, among other strategies, hyperhydration.

Other scholars (among them Marius Nielsen and Timothy Noakes) claim that postrace core temperatures of between 102.2 °F (39 °C) and 105.8 °F (41 °C) are usual in athletes who exercise at high intensities, because the magnitude of deep body temperature elevation is proportional to metabolic rate. Regarding a possible connection between dehydration and heat illnesses, they cite research results that show that whereas skin temperature is related to air temperature and is independent of the level of exercise, on the contrary, core temperature is related to the level of exercise and quite independent of the environmental conditions. For these reasons, they doubt if there is a close connection between dehydration and heat illnesses and reject the hyperhydration technique. Also, the 2007 Position Stand by the American College of Sports Medicine states that hyperhydration does not provide a clear physiological or performance advantage over euhydration.

Variability Factors

All researchers agree, however, that many variability factors can decrease or, vice versa, increase exercise-induced dehydration. Dehydration can be worsened by the following factors:

Environmental and Climatic Conditions: High air temperatures (greater than 80 °F, or 27 °C), high relative humidity (above 60%), high radiant heat load from surfaces (e.g., black asphalt), sprinkler systems running before practice, high altitudes (more than 6,600 feet, or 2,000 meters, above sea level), low-speed air movement (lower than 9 miles, or 15 kilometers, per hour) during exercise, long journeys in hot environments to reach the event venue, absence of air conditioning in athletes' living and sleeping accommodations, and insufficient graduality in the acclimatization process.

Health and Fitness Conditions: Chronic illnesses such as diabetes, asthma, kidney diseases, cystic fibrosis, heart conditions, and epilepsy; present or recent flu; viral infections; gastroenteritis; vomiting or diarrhea-causing illnesses; previous heat-related illnesses; use of medications such as antihistamines, diuretics, some blood pressure medications, and psychiatric drugs; rare or irregular participation in sports or physical activities; and excessive body mass index (BMI).

Clothing and Equipment: Wearing of heavy, dark-colored garments and uniforms that do not facilitate sweat evaporation and the use of complete protective equipment with helmets and/or insulating, bulky, leather, or rubber parts when the subject is unaccustomed to it.

Specific Characteristics of Some Physical Activities: High exercise intensity and duration, specific sports rules that limit the opportunities for fluid replacement during scheduled breaks, scarce availability of water and/or beverages (e.g., in cross-country racing or skiing), and inadequate time for drinking.

Athletes' Gender and Age: Being a female athlete (women have a greater percentage of body fat, and the water content of fat cells is very low), being an older athlete (seniors' ability to conserve water in their body is reduced; their thirst sense is less acute), and being a pediatric athlete (in children, the body water and electrolyte turnover is higher than in adults).

However, there is great variability in sweating rates among individuals, even if they are exercising in trials where conditions are standardized.

Prevention

Prevention can be achieved through organizational measures and water and salt intake strategies.

Organizational Measures

The following measures may be taken:

- Schedule gradual and increasing exposure to intensity, duration, and protective equipment, taking into account activities other than exercising.
- Schedule regular breaks to limit excessive physical activity and to permit fluid replacement.
- Acclimatize to high-temperature, high-humidity, and/or high-altitude venues; limit practice during the first days; and avoid the hottest part of the day.
- Wear lightweight, light-colored, loose-fitting garments.
- Gradually accustom yourself to protective equipment.
- Monitor exercise-induced weight loss, which is primarily due to water loss.

Water and Salt Intake Strategies

Intake of water and salt should be regulated as follows:

- Remember that thirst may not be an effective indicator of hydration status while exercising, because it is not perceived until body water deficit reaches approximately 2%.
- Consume fluids so as to be euhydrated before, during, and after exercise.
- Limit consumption of caffeine- and alcohol-containing drinks, as they increase urine output.
- Consume drinks and foods that can prevent and/or replace excessive water and salt losses, such as sports drinks, fruit, and vegetables.
- Choose chilled water and drinks with temperatures ranging from 50 °F (10 °C) to 72 °F (22 °C).

Alessandra Padula

See also Diuretics; Muscle Cramps; Nutrition and Hydration; Salt in the Athlete's Diet; Sports Drinks; Temperature and Humidity, Effects on Exercise

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Dental Injuries

Dental injuries are the most common orofacial injuries that occur in sports, and treatment can involve considerable expense. There is a 10%-per-year chance of an orofacial injury for those playing contact sports and a 33% to 50% chance of an orofacial injury during an athlete's career. Of all sports injuries, 13% to 39% are dental related. Most of these injuries are preventable, however, with correct use of a good mouthguard.

Classification

Most dental injuries are classified by location: soft tissue injuries or injuries to the teeth.

Soft Tissue Injuries

Soft tissue injuries are often difficult to assess initially because of excessive bleeding. Most of the injuries are lacerations to the lips, cheek, gingiva, mucosa, frenulum, and tongue—all composed of highly vascular tissue. These injuries are mainly treated by obtaining good hemostasis, careful cleansing, and suturing. When suturing the lips, the physician needs to make sure that the vermillion border of the lip approximates well.

Injuries to the Teeth

There are either avulsions (the entire tooth is knocked out), luxations (the tooth is still in place but in the wrong position), or fractures.

Anatomy of the Tooth

The hard exterior of the tooth is the enamel. The subsequent deeper layers are the dentin and the pulp when in reference to the crown—the portion of the tooth that is not below the gum line. The root of the tooth, below the gum line, includes the periodontal membrane, cementum, dentin, and pulp.

Avulsion

Once a tooth is completely knocked out, it is imperative for a dental professional to try to reimplant it as soon as possible. It is important not to handle the tooth by its root, sterilize it, or scrub it. It should be rinsed with clean water prior to efforts to reimplant the tooth back into its socket. (Primary or "baby" teeth are unsuitable for reimplantation.) If immediate reimplantation is not possible, the tooth should be transported in Hanks' Balanced Salt Solution or cold whole milk. If none of these is available, then the next best transport media in order are saline solution, under the patient's tongue, and in water. Do not transport on ice or wrap the tooth in gauze. Reimplantation is best done within 30 minutes of the injury. Hank's Balanced Salt Solution can keep a tooth viable for about 24 hours, whereas the other transport media can keep the tooth viable for only a few hours.

Luxation

There are three types of luxation: (1) extruded (the tooth is higher than it should be/than the surrounding teeth), (2) lateral displacement, and (3) intruded (the tooth is lower than it should be/than the surrounding teeth). For both, the extruded tooth and the laterally displaced tooth, repositioning on the field can be done. The intruded tooth should not be repositioned. Immediate consultation should be done with a dental professional as soon as possible, whether or not the tooth has been repositioned.

Fracture

The broken tooth should be saved in the best transport medium available (see above). These can be extremely painful problems, especially if the pulp is exposed. It is important to try to minimize contact of the exposed pulp to air, other teeth, or the tongue, because it will be highly painful. Transport the athlete and the tooth fragment to the dentist immediately.

Mouthguards

A good mouthguard should cover the upper and/or lower teeth and gums, be fitted so as not to misalign the jaw and throw off the bite, be light, be strong, be easy to clean, and allow the athlete to communicate and breathe easily without moving or manipulating the mouth protector. Often, a proper mouthguard will have a 3-millimeter (mm) labial thickness, a 2-mm palatal thickness, and a 3-mm occlusal thickness. The common types of mouthguards available are stock, boil-and-bite, vacuum custom, and pressure-laminated custom. Ninety percent of mouthguards are store bought, and 10% are custom fitted.

The stock and boil-and-bite types are the cheapest, but they are also the least sturdy and often are too thin to protect the teeth well. Seventy percent to 90% of the occlusual thickness is lost in the molding process for the boil-and-bite mouth protector. They are also not capable of being modified to accommodate athletes with poor bite occlusion or other dental issues. They often interfere with speech and breathing.

Vacuum mouthguards are made from a stone cast of the maxillary arch. They are good for single-layer mouthguards. These guards allow better communication and stay in place well.

The laminated mouthguard consists of two or three layers of ethyl vinyl acetate, and it is molded over a cast. Its advantages are that it wears longer and it is possible to place inserts for increased thickness.

The American Dental Association estimates that mouthguards prevent 200,000 injuries annually in high school and college football. The cost of tooth reimplantation and follow-up exams can total $5,000. If a tooth is not properly preserved, the costs can be from $15,000 to $20,000.

Nilesh Shah

See also Craniofacial Injuries; Facial Injuries

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Dermatology in Sports

Athletes experience a wide range of dermatological conditions that can be related to their sports training and competition and to the environment in which they train and compete. Athletes can also experience other non–sports-related general dermatological conditions, such as acne and eczema, which can be exacerbated by their respective sport. Skin conditions can affect an athlete's performance and, in some cases, can temporarily exclude the athlete from participation in the sport. Prompt and accurate care of skin conditions can reduce the time out of training and competition. Dermatologists should not only diagnose and treat such skin conditions, but they should also play a role in the education and prevention of skin disorders in athletes.

General Skin Care

General skin care is important in athletes to maintain the skin barrier and allow the skin and sweat glands to function correctly. The skin is subject to trauma, friction, and other environmental injury during sports. Xerosis (dry skin) is often seen in athletes due to a combination of factors, including the need for taking multiple showers after competition and training, due to the cold-weather environment in winter sports and the continuous immersion in chlorinated water in water sports. Athletes with a history of atopy (the genetic tendency to develop the classic allergic conditions—rhinitis, atopic dermatitis, and asthma) will also be at increased risk for xerosis and worsening or inducing of their atopic dermatitis. A gentle soapfree skin cleanser should be used whenever possible, followed by a light moisturizer after each shower. If acne, frictional, or occlusion folliculitis is a problem, an antibacterial soap or benzoyl peroxide–based wash can be added for the infection-prone areas, followed by a light, nongreasy moisturizer. Each athlete should use only his or her personal soap, and soap should not be shared. Towels should also not be shared with other team members. Skin should also be protected from friction and trauma by using appropriately fitted protective gear and pads. Inappropriately fitted sports equipment can lead to contact irritant dermatitis and friction blisters of the skin. Any skin disorder should be promptly assessed and treated to ensure rapid resolution and continued participation of the athlete in his or her sport at peak-performance level.

Athletes can present with general non–sports-related dermatoses, or they can have worsening of a preexisting dermatosis, such as acne. Acne can be exacerbated due to sweating/perspiration and sunscreen if used by the athlete. Acne mechanica can be a problem for athletes where friction, sweat, and occlusive forces coincide, such as around helmet straps, tight-fitting uniforms, and other sports equipment. As well as following standard acne treatment with oral antibiotics such as minocycline or doxycline, athletes need to wash acne-prone skin with a benzoyl peroxide or salicylic acid preparation immediately after participation in their sport to reduce the time the skin is exposed to sweat. Application of a topical acne antibiotic such as clindamycin lotion to the involved areas should then follow. It should be remembered that some medications, including doxycycline for acne, can render the skin photosensitive and more prone to sunburn. Athletes should be warned of this risk, and an oilfree sunscreen should be used. Absorbent cotton garments can help absorb sweat and prevent friction from contact with equipment.

Sports-Associated Skin Conditions

Athletes can present with dermatologic conditions associated with their sport and its mechanics, and dermatologists should be familiar with these characteristic skin findings of the sport. For example, turf toe presents as tendinitis in the great toe of athletes who play soccer and football on turf. Footwear designed for turf can assist in preventing this injury. Athlete’s nodules occur in surfers and boxers from recurrent friction or trauma on the dorsal feet and knuckles. These injuries can be mistaken for other dermatological conditions such as acute gout instead of turf toe or an infective or neoplastic process instead of athlete’s nodule. It is important to recognize that these injuries are a consequence of the athlete’s respective sport in order to ensure their appropriate treatment and prevention.

Foot care is important for all athletes, especially runners. Runners are at risk for corns, ingrown toenails, dystrophic toenails, and talon noir on the feet. Corns can develop due to improperly fitting shoes or due to existing bony abnormalities of the feet. Salicylic plasters and mechanical paring can relieve corns, and padding is needed to protect the area. Referral to a sports surgeon may be needed to assess the underlying foot abnormality. Nail dystrophy, such as discoloration, onycholysis, and subungual hyperkeratosis, can be seen due to repetitive trauma on the nail from the shoe in sports such as tennis, other racquet sports, and basketball and can be occasionally mistaken for onychomycosis. Hemorrhage into the nail from sports trauma can sometimes be mistaken for melanoma, and a nail biopsy should be performed if a melanoma is suspected. Ingrown toenails and nail dystrophy can be prevented by shoes being properly fitted and the nails being trimmed straight across.

Runners and other athletes involved in sports with mechanical shearing and frictional forces on the feet and also the hands are also at risk for calluses and frictional blisters. Calluses can be reduced mechanically or be padded for protection. In some sports, calluses may provide a competitive advantage, and the athlete may only reduce them in the off-season. The treatment of frictional blisters involves cleansing and protection with a synthetic dressing. Skin care of areas exposed to weight-bearing forces and equipment contact surfaces is essential to reduce the risk of injury to these important areas. Athletes should be educated on the care, treatment, and prevention of these common injuries. Correct fitting of running shoes and sports equipment can reduce the likelihood of friction blisters developing. Moisture-wicking socks can also help prevent blisters on the feet.

Skin Protection

Protection of the skin from the environment is also important for athletes. Athletes are at risk for environmental skin injuries from exposure to ultraviolet (UV) light, cold, and water. Winter athletes are at risk for cutaneous cold injuries, such as frostbite and cold panniculitis. Multiple layers of warm protective clothing can help prevent these skin injuries. Both summer and winter athletes are at risk for sunburn and skin neoplasms. Often, training and competition programs are played during the highest-UV times of the day, increasing the chance of sunburn in athletes. Chronic sun exposure and multiple sunburns increase the risk of skin photoaging and skin cancer, including melanoma. Athletes and their coaches should be educated on the correct sun protection strategies. Ideally, the sports and training schedules should be outside the high-UV times, but this is not always possible. Winter sports athletes are also at risk for sunburn on exposed skin, and the UV intensity is much higher at high altitude than at sea level. Regular application of sunscreen on exposed skin is essential, and sun protective clothing such as hats should be used where possible. Sunscreen preparations in the form of sprays and gels are usually preferred by athletes when participating in sports, rather than lotions and creams. Appropriate sunscreens should offer broad-spectrum protection from UVA and UVB and be water resistant with a high to very high sun protection factor (SPF) rating of 30+ to 50+. High–UV protection clothing ranges are also available to provide better sun protection for athletes. Some laundry washing powders such as SunGuard by Rit also confer clothes with a UV protection factor after washing to reduce UV radiation through clothing. Eye protection should also be worn by athletes whenever possible to prevent eye UV injuries.

Skin Infections

Athletes are at risk for infective conditions from viral agents, bacteria, fungi, and parasites. Close contact during sports, the hot humid conditions of locker rooms, sharing of sports equipment, and inadequate cleaning of sports equipment can predispose athletes to a variety of skin infections. The dermatologist's role is not only to treat the infection but also to advise and educate athletes and coaches regarding the appropriate prophylactic measures to reduce the risk and prevent infection from spreading to other competition and team members. Herpes gladiatorum, from herpes simplex virus-1 (HSV-1), is most commonly seen in wrestlers and can be proven by positive HSV-1 culture. Staphylococcal and streptococcal infections can also be spread by similar close contact during sports. These infections should be treated with appropriate oral agents. Infection can be avoided by careful skin hygiene, with showering before and after sports participation; adequate regular cleaning of sports equipment; and preventing any athlete with an active skin infection from competing until the skin infection is treated and healed.

Conclusion

Good skin care and use of well-fitting shoes and sports equipment can prevent skin and nail trauma and frictional injury. Athletes and coaches should be educated on correct skin and nail care and be aware of the skin injuries specific to their sport. This can help prevent these conditions and enable the athletes to maintain training schedules and optimal performance. Athletes should also be aware of the risks of melanoma and other skin neoplasms plaguing sports associated with UV exposure. Adequate sun protection is essential for these athletes. Some sports-related skin conditions and injuries require a dermatologist referral, while other injuries can be treated with simple cleansing and dressings. Non–sports-related skin conditions should never be ignored as a differential diagnosis in athletes.

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See also Allergic Contact Dermatitis; Irritant Contact Dermatitis; Skin Disorders, Metabolic; Skin Disorders

Affecting Sports Participation; Skin Infections, Bacterial; Skin Infections, Viral; Skin Infestations, Parasitic; Sunburn and Skin Cancers

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Detached Retina

The wall of the eye is made up of three layers. The outermost layer is called the sclera; the innermost layer is the retina. The retina is further divided into an outer layer of pigmented epithelium and an inner layer of neural tissue. When the inner neural tissue separates from the outer pigmented epithelium, this abnormal condition is called *retinal detachment.* There are three types of retinal detachment, depending on the mechanism:

1. *Rhegmatogenous.* This is the most common. A break or tear in the inner neural layer allows vitreous fluid from within the eye to seep into and hydro-dissect the external epithelial layers.
2. *Traction.* Increased tension from retinal adhesions pulls the inner and outer layers of the retina apart. The formation of poorly structured retinal vessels, such as in diabetic retinal disease, is a common cause of tractional retinal detachment.
3. *Exudative.* Fluid from retinal vessels leaks between the outer layer of pigmented epithelium and the inner neural layer, separating the layers. There is no tear or break in the retina, but the fluid often accumulates from inflammation or because of a tumor.

Most retinal detachments occur in persons between the ages of 40 and 70 and are often seen after cataract surgery. Additionally, those with proliferative retinopathy from diabetes or sickle cell disease are at increased risk for traction-type retinal detachment due to blood vessels pulling the retina away from the back wall of the eye.

Specifically, in the field of sports medicine, retinal detachments can be due to various causes. Direct trauma to the eye from high-velocity objects (e.g., racquetballs, paintballs) causes vitreoretinal traction from globe compression and decompression. The detachment may not be immediate. This can be prevented in a majority of cases by wearing proper eye protection. Blunt trauma to the eye or facial area in sports such as boxing and mixed martial arts can lead to retinal detachments, although rarely. More likely are retinal tears that can be found on routine eye examinations. Additionally, athletes with severe nearsightedness (myopia) are more prone to retinal detachments. This seems related to pressure changes in the eye due to straining. This may be seen in weight lifters or scuba divers. Rapid acceleration or deceleration (drag racing) may also place an individual at increased risk for retinal detachment.

Signs and Symptoms

Retinal detachment is usually not painful. Rather, patients may complain of wavy, cloudy, or distorted vision. They may describe seeing flashes or floaters. Visual field loss is usually sudden and unilateral and progresses from the edges to the center. This leads to poor visual acuity (20/200 or worse).

Management

If retinal detachment is suspected, urgent evaluation by an ophthalmologist is required. Surgical repair is often necessary. Time is critical because an important consideration is the length of time the retina is detached before repair. Untreated retinal detachments can lead to blindness in the affected eye.

Prognosis

The majority of retinal detachments can be repaired surgically. Many postsurgical patients obtain visual acuity of 20/70 or better. Some repaired retinas will redetach, usually within 6 weeks following surgery. Continued follow-up with an ophthalmologist is prudent.

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See also Eye Injuries; Protective Equipment in Sports

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Detraining (Reversibility)

Athletes and exercisers worry that their performance or fitness levels will diminish if they cannot train because of injury, illness, travel, or other circumstances. Although there is some truth in the "Use It or Lose It" warning often given by doctors, therapists, trainers, and coaches, the process of becoming detrained, or deconditioned, is not that simple.

Detraining is a reduction or complete loss of fitness as a result of not training. What happens during a period of detraining depends on the physical condition of the person before stopping an activity, how long that person stops training, and which area of fitness is affected by the inactivity (e.g., strength, aerobic capacity, or flexibility).

Various studies have shown that detraining can result in decreased $\dot{V}O_2max$ (the ability to take in, transport, and use oxygen for fuel; see below), diminished breathing function, increased heart rate, and an early lactate threshold (the point at which intensive exercise causes a buildup of blood lactate), as well as loss of strength and flexibility. In general, stopping training produces a significant loss in conditioning after 2 to 6 weeks. Following are some evidence-based, specific examples of how detraining may affect various physical functions.

Effects of Detraining

$\dot{V}O_2max$

Highly trained athletes show a 5% drop in $\dot{V}O_2max$ during the first 3 weeks of inactivity. A slower decline occurs during the following weeks. (*Journal of Applied Physiology*, Volume 63, 1987)

Endurance athletes who reduce or cease training do not fall to the levels displayed by persons who have never trained. (*Journal of Applied Physiology,* December, 1984)

Persons with low to moderate aerobic capacity show little effect of detraining during the first 3 weeks, but $\dot{V}O_2max$ declines to untrained levels after several additional weeks. (*Georgia Tech Sports Medicine & Performance Newsletter,* February, 2000)

Respiratory Capacity

After 5 months of intense training followed by a period of inactivity, swimmers show a 50% decrease in respiratory capacity after the first week. (*Medicine & Science in Sports & Exercise,* Volume 17, 1985)

Stroke Volume

Stroke volume (the amount of blood pumped with each heartbeat) begins to decrease as soon as training is stopped. One study showed a 10% decline within 12 days, and another indicated a 12% drop 2 to 4 weeks after the last training session. (*Exercise*

Physiology, "Deconditioning and Retention of Adaptations Induced by Endurance Training," 1998)

Blood Volume

Blood volume in endurance athletes is reduced by 5% to 12% within 48 hours. (*Journal of Applied Physiology,* Volume 60, 1986)

Strength/Muscle Mass

Detraining may result in a decrease of muscle mass and strength. (*ACSM Resource Manual for Guidelines for Exercise Testing and Prescription, 2005*)

High-intensity training may help a person maintain any gains in strength for longer periods after training has stopped. (*Exercise Physiology,* "Deconditioning and Retention of Adaptations Induced by Endurance Training," 1998)

Heart Rate

Resting heart rates increase with inactivity, which indicates a decline in cardiovascular endurance. However, among well-conditioned athletes, the rates do not change significantly after the first 2 to 3 weeks of inactivity. (*Sports Medicine,* Volume 33, 2003)

Maximal heart can decrease from 5 to 13 beats/minute with aerobic training and increase from 4 to 10 beats/minute with tapering or detraining. (*Sports Medicine,* Volume 29, 2000)

Flexibility

Among older adults, the components of fitness most affected by detraining are lower extremity flexibility after 2 to 4 weeks of detraining and agility/balance after 6 weeks of detraining. (*British Journal of Sports Medicine,* August, 2005)

Sports Performance

The exact effect of detraining on performance is difficult to determine because of the many variables involved, including the physical condition, the intensity and duration of training, and the nature of the sport.

Endurance performance is markedly impaired if training is stopped for 4 weeks. (*Medicine and Science in Sports and Exercise,* March, 2001)

Endurance capacity is reduced by 21% after 4 weeks of detraining. (*Journal of Applied Physiology,* October, 1993)

In highly trained individuals, interruption of training causes a decline in sports performance. Marathon runners posted a 25% decrease in endurance after 15 days of inactivity. Swimmers showed a 14% decrease in maximal arm power after 4 weeks of not training. (*Medicine & Science in Sports & Exercise,* September, 2006)

Among soccer players, detraining may result in a decrease in the time to exhaustion by 24% in 5 weeks. However, a training break of 2 weeks does not appear to produce a significant change in time to exhaustion. (*Research Quarterly,* Volume 40, 1969)

Minimizing the Effects of Detraining

Whatever the potential loss of conditioning, it can be minimized in several ways. Cross-training (participating in other sports or exercise programs) allows an athlete to remain active while not training specifically for his or her sport. For example, water running or brisk walking might be substituted for jogging, distance running, or skiing. Upper body lifts can be performed when an injury prevents lower body training. Resistance training outside the pool might be continued even though a swimmer has to stay out of the water for a period of time. In some cases, athletes may be able to continue participating in their respective sport or activity, but at a less intense or frequent level.

The good news regarding detraining is that, for most exercisers, resuming a training program within 6 weeks may restore previous levels of fitness in less time than it might have taken if those individuals had started from a completely untrained level.

Jim Brown

See also Bioenergetics of Exercise and Training; Gender and Age Differences in Response to Training; Overtraining; Principles of Training

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Diabetes in the Young Athlete

Diabetes mellitus (DM) is a chronic endocrine disorder characterized by hyperglycemia (elevated blood sugar), caused by decreased insulin secretion by the pancreas, decreased insulin sensitivity at the tissues, or both. Children with DM have many lifestyle adjustments to make to regulate their blood glucose (sugar), but in general, DM should not limit their ability to participate in sports. In fact, physical activity is an important aspect of maintaining health and preventing the long-term complications of DM. Regular exercise helps children with diabetes achieve and maintain a healthy weight, minimize the addition of more and/or higher doses of diabetic medications, and helps control blood glucose levels, cholesterol, blood pressure, and cardiovascular functioning.

Prior to beginning a new exercise program, diabetic children should be evaluated by an endocrinologist or pediatrician. In a juvenile population, the biggest risks of exercise involve hyperglycemia or hypoglycemia (low blood sugar) during or postexercise. In older individuals with diabetes, other long-term health consequences of poorly controlled diabetes predispose to injury. These include neurologic, eye, and kidney problems, as well as cardiovascular disease. These are beyond the scope of this entry, which will focus on diabetes management and exercise in a younger population.

Types of Diabetes Mellitus

The two types of DM are as follows:

Type 1 DM accounts for 10% to 15 % of all cases of diabetes and is the most common type of diabetes in children. It is characterized by the destruction of pancreatic beta cells, leading to deficient insulin production but normal insulin sensitivity at the tissues.

Type 2 DM accounts for the majority of the other 85% to 90% of cases. It is characterized by variable abnormalities in insulin secretion and insulin sensitivity. It begins with poor insulin sensing, thus inhibiting the body's ability to draw glucose out of the bloodstream and into the cells. Eventually, Type 2 DM can progress to pancreatic beta cell destruction, leading to impaired insulin production and secretion. With increasing childhood obesity, Type 2 DM is on the rise.

Other forms of pediatric diabetes include secondary diabetes, caused by some other medical condition, such as cystic fibrosis or Down syndrome, and maturity-onset diabetes of the young (MODY). New categories of DM are being added as we learn more about genetic and environmental predisposing factors. But in general, it is most important to know if the pediatric athlete's disease is more similar to a Type 1 or Type 2 DM. Also, knowing about the child's general diabetes control regimen is important in anticipating his or her response to athletic activity and medical treatment. Thus, in this entry, variations of DM will only be referred to under the global categories of Type 1 and Type 2.

Types of Diabetes Mellitus Treatment

The primary goal of diabetes management is to keep blood glucose (sugar) close to the normal range without causing hypoglycemia. There are various medication regimens to help achieve this goal. For some individuals with Type 2 DM, this may include a form of insulin. For Type 1 DM, insulin is always indicated. All types of insulin must be injected using a pen or syringe, or a pump (there are no pill forms), but different types of insulin vary in onset, peak, and duration of action. Rapid-acting insulins take effect within 10 to 15 minutes of injection, peak within 1 to 2 hours, and last for 3 to 5 hours. Long-acting insulins take 1 to 3 hours to begin lowering glucose, have a steady level of control with no peak, and wear off in around 24 hours. Short-acting, intermediate-acting, and premixed combination insulins have onsets, peaks, and durations somewhere in between depending on the type and brand.

There are a variety of oral and noninsulin injectable medications that help with glucose control, particularly for Type 2 diabetics. It is important to know if a child is on oral agents that could contribute to hypoglycemia (e.g., meglitinides and sulfonylureas).

Hypoglycemia

Exercise has an insulin-like effect on blood glucose. Glucose is drawn out of the blood as the muscles require energy to work, thus putting diabetic athletes taking insulin or other medications that lower the glucose level at risk for hypoglycemia. Multiple factors contribute to the variability of such exercise effects: (a) blood glucose concentrations before initiating exercise, (b) the time relation of exercise to meals, (c) basal/bolus (long-acting/short-acting) insulin doses, (d) an individual's physical fitness level, (e) his or her insulin sensitivity, and (f) the adequacy of his or her counterregulatory hormone responses to exercise.

In people without DM, insulin levels decrease during exercise, but in DM patients who take injectable insulin, the levels do not decrease with activity. Increased insulin impairs liver glucose production and can induce hypoglycemia within an hour of initiating exercise. Counterregulatory hormones (e.g., glucagon, catecholamines, growth hormone, and glucocorticoids), which normally increase glucose levels, may be impaired in patients with long-standing diabetes. Also, exercise improves insulin sensitivity in skeletal muscle, leading to postexercise, late-onset hypoglycemia. This can occur more than 24 hours after activity and is especially dangerous if it occurs when the athlete is asleep and unaware of the symptoms.

In general, the signs and symptoms of hypoglycemia occur when blood glucose drops below 70 milligrams/deciliter (mg/dl), but this number varies among individuals. Sweating, rapid heart rate, palpitations, hunger, nervousness, trembling, headache, dizziness, and mood changes are early symptoms. Unfortunately, these are often hard to differentiate from the responses experienced during vigorous exercise. If the blood glucose level continues to fall, more severe symptoms may be observed, which include fatigue, blurry vision, impaired thought, loss of coordination, aggression, confusion, seizures, and loss of consciousness.

Each individual has his or her own specific response to hypoglycemia, and ideally, the parents, coach, and team medical support should be familiar with these prior to the child's participation in sports.

Every athlete should have an action plan to use when hypoglycemia is suspected. The following is a guide:

1. He or she should test the blood sugar level with a glucometer.
2. If the level is low, he or she should eat or drink foods with simple sugars, such as three glucose tablets, a few jelly beans, some honey, half a cup of fruit juice, or other quickly absorbable sugary food (the amount and type of emergency snack should be discussed ahead of time with the athlete's doctor).
3. The blood sugar should be tested again in about 15 minutes, and if the number is below 100 mg/dl or the child does not feel well, he or she should not return to play.
4. After a hypoglycemic episode, the child should be monitored closely with frequent glucometer testing.
5. Medication and pre-exercise snacks should be reviewed and adjusted to help prevent future episodes.
6. Athletes should always have sugar available, as well as a glucagon kit (glucagon has the opposite action of insulin).

Hyperglycemia

In DM children who produce or take too little insulin and/or have poor baseline control, high-intensity (anerobic) exercise leads to increases in blood glucose levels. High-intensity exercise is associated with increases in catecholamines, free fatty acids, and ketones (ketones are the toxic by-products produced when the body burns stored fat instead of glucose for energy), all of which decrease the muscles' utilization of glucose and increase the blood sugar.

In the well-controlled athlete, these changes may be transient (decreasing in less than an hour), but poor insulin balance along with stress regarding sports performance may increase counterregulatory hormones and perpetuate the hyperglycemia.

In Type 1 DM, hyperglycemia and ketosis lead to a severe condition known as *diabetic ketoacidosis* (DKA). It involves a severe lack of insulin, which if left untreated could lead to coma or even death. Symptoms of DKA include nausea, vomiting, weakness, abdominal pain, dehydration, heavy breathing, and fruity-smelling breath.

As with hypoglycemia, diabetic athletes need a plan for suspected hyperglycemia, such as the following.

Type 1 DM

If fasting glucose (blood sugar ≥4 hours after eating a meal) is ≥250 mg/dl, check for ketones. If positive, the athlete should not exercise and should be treated for DKA. (This involves hydration, insulin, and possibly other medical support.) If fasting glucose is between 251 and 350 mg/dl and ketones are negative, it is important to hydrate, but it is okay to perform physical activity. If fasting glucose is >350 mg/dl, regardless of the ketones result, the athlete should hydrate, should not return to activity that day, and should have dietary/medication adjustments made.

Type 2 DM

If the fasting glucose of a child with Type 2 DM is ≤350 mg/dl, he or she should hydrate but may return to play. If the glucose is >350 mg/dl, the athlete should hydrate, should not return to activity that day, and should have dietary/medication adjustments made.

Prevention

Each athlete with DM should have a care plan for training as well as for matches/games/races. These should be familiar and available to the parents, coach, and team medical support staff and should include the following:

Blood glucose monitoring equipment and directions

- A medication list with doses and directions
- Hypoglycemia and hyperglycemia action plans along with ketone test strips for Type 1 DM
- Doctor and parent contact information
- The athlete should also have a medical alert tag with him or her at all times.

Fasting glucose should be checked, and the pre-exercise meal should be ingested 1 to 3 hours before the activity, should consist of low–glycemic-index foods (complex carbohydrates, not simple sugars), and should include protein to ensure continuous, but not too rapid, glucose absorption. Immediately before the activity, the athlete should check his or her blood sugar again, with an ideal goal of 120 to 180 mg/dl. The child should continue to monitor his or her blood glucose throughout the sporting activity, supplement with carbohydrates when needed, and continue to hydrate and reassess every 30 to 60 minutes depending on his or her baseline control and exercise levels.

Often, as athletes become more experienced with monitoring their glucose control and training habits, these intervals may be lengthened. Seasoned athletes often get to a level of awareness of their personal responses to exercise such that they know when to consume extra carbohydrates or check their blood sugar based on their exercise duration and/or symptoms.

Those using insulin should inject in areas away from exercising muscles approximately 1 hour before activity, as exercise, massage, and heat can increase the rate of absorption. If possible, the athlete should try to anticipate the intensity and duration of the activity to better adjust the insulin dosing and carbohydrate intake. In general, as the intensity and duration of the activity increase, less insulin is required.

Insulin Pumps

DM individuals using insulin pumps receive insulin through a continuous subcutaneous (under the skin) infusion. They may have basal insulin settings that are constant or vary throughout the day. In addition, pump users have bolus insulin doses administered prior to meals. Insulin pump settings may be adjusted prior to sports participation, and requirements may change as the child becomes more fit.

Depending on the activity, the child's preference, and the endocrinologist or pediatrician's recommendation, pump users may discontinue the pump during sports participation and switch to injectable insulin. If the pump is removed before physical activity, hyperglycemia is more of a risk, and a long-acting injectable insulin should be used appropriately. If the pump is continued during activity, pump malfunction or detachment (e.g., from contact or sweat) may lead to hyperglycemia, overinsulinization, and subsequent hypoglycemia. Insulin pump athletes who experience hyperglycemia or hypoglycemia should always have their pumps examined immediately.

Conclusion

While general guidelines may be helpful for a diabetic child athlete, diabetes is a very individual disease. Thus, parents and children should work closely with their doctors to develop a care plan and make it known to coaches and others involved in the athlete's sports activity. The athlete should keep a log of glucose levels, the dosing of insulin and other medications, dietary intake, and exercise to better understand his or her individual dietary and medication needs with various activities. Such knowledge, with ongoing adjustments, will improve glucose control and help prevent hypoglycemia/hyperglycemia. Staying active and diligently trying to improve and maintain glucose control will not only enhance sports participation but also minimize the long-term sequelae of diabetes.

Kathryn E. Ackerman

See also Diabetes Mellitus

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Diabetes Exercise and Sports Association: http://www.diabetes-exercise.org

Diabetes Mellitus

Diabetes mellitus is a condition characterized by a relative insulin deficiency resulting in an abnormal fuel-hormone response, especially when challenged by the ingestion of food. This abnormal fuel-hormone response involves decreased storage and utilization of fuels and results in elevated blood levels of glucose, free fatty acids, and ketones. Diabetes results from a deficiency in the insulin-secretory mechanism of the beta cells of the pancreas, a faulty insulin receptor site on the cell surfaces of liver, adipose, and muscle tissue, and/or a metabolic defect in the cell itself.

There are two basic types of diabetes, insulin dependent and non–insulin dependent. Insulin-dependent diabetics are usually under 20 years of age at the onset of the disease and constitute less than 10% of the diabetic population. Their symptoms at the onset of diabetes are acute, coming speedily to a crisis: Metabolic ketoacidosis and insulin reactions are frequent, insulin production is decreased, the potential for developing maximal sports performance capacity is reduced, and hyperglycemia usually results from the marked reductions in glucose storage and utilization. Non–insulin-dependent diabetics, however, are generally over 40 years of age at the onset of diabetes; they are overweight and constitute more than 90% of all diabetics. Most have a family history of diabetes, the appearance of their symptoms is slow, they show a delayed insulin response to eating a meal, and hyperglycemia often results owing to the failure of the liver to retain glucose and to a small impairment in glucose oxidation.

Insulin-dependent diabetes treatment requires insulin replacement therapy, which must be appropriately balanced with the dietary intake and energy expenditure. The goal of treatment is to normalize the storage and utilization of metabolic fuels by attempting to keep the blood glucose level as close to normal as possible.

The non–insulin-dependent diabetic exhibits a delayed rise in insulin secretion in response to eating. In other words, instead of reaching a peak insulin secretion in response to a carbohydrate meal in 1 hour, the response is delayed until 2 hours. This type of diabetic also has less liver retention of glucose, which leads to increased blood sugar in the circulation after a meal and a somewhat lower than normal rate of utilization of glucose by muscle and adipose tissues. The majority of such diabetics are overweight or obese and have a low oxidation rate for carbohydrates, which is believed to be because the interaction of insulin at the cell surface or within the cell itself has been reduced. Aerobic exercise can enhance this vital interaction of insulin at the cellular level.

Inadequate physical activity and excessive caloric intake are the two most important environmental factors influencing the development of diabetes. Endurance exercise programs have a great potential for the restoration of normal metabolism, since both loss of weight and endurance training enhance the action of insulin—that is, make it more potent. Moderate sustained activity will result in a gradual reduction in blood glucose as the exercising muscle takes up and uses that glucose for energy. This decrease will frequently last for 1 or more days after the exercise ceases. Endurance exercise also increases cellular sensitivity to insulin, thus the same amount of insulin will allow the cell to use an increased amount of sugar.

The use of exercise in the treatment of diabetes is certainly not new: It was recommended as a therapy for the disease as far back in antiquity as 600 BCE by Chao Yaun-Fang, an eminent Chinese physician of the Sui Dynasty.

Through the years, many noted specialists have recognized the value of regular physical activity to the diabetic and have encouraged their patients to exercise. However, they offered this advice sporadically and in an unspecific way. In contrast to diet and insulin therapy, exercise was not given priority in the treatment of diabetes. It is now quite evident that exercise is critical to the prevention and management of diabetes, and thus sports, especially aerobic sports, are to be encouraged.

Today, there is an increased recognition that individuals with diabetes mellitus can participate in sports and derive benefits equal, in terms of enjoyment and improved good health, to those achieved by nondiabetics. In addition, exercise, when integrated with a total diabetes treatment plan, offers unique advantages in terms of improved blood glucose regulation.

Exercise has advantages specific to the diabetic. First, exercise increases the receptivity of muscle to insulin. Normally, a given amount of insulin will cause a certain amount of glucose to be picked up by a muscle cell. If that cell is exercised, the amount of glucose that is picked up is significantly increased. Thus, the same amount of insulin will allow increased amounts of glucose to be transferred from the bloodstream into the muscle.

Second, exercise helps by decreasing excess fat and increasing the body cells' sensitivity to insulin. Obesity itself reduces sensitivity to insulin, thereby increasing a person's chances of acquiring diabetes and the complications from the disease. It is estimated that exercise and diet alone, by preventing obesity, can eliminate the occurrence of most adult-onset diabetes.

Third, exercise reduces the triglycerides and low-density lipoproteins in the blood, which leads to better control of the diabetic state. In addition to these advantages, which are unique to the diabetic, exercise also affords the diabetic the same (more than 30) cardiovascular, pulmonary, circulatory, and emotional benefits that everybody else receives from exercise, such as feeling better, having a better outlook on life and oneself, and having more energy.

Thus, having diabetes should make one want to be physically active and is no contraindication to sports participation. Indeed, diabetics have been superstars in all sports, from Jim "Catfish" Hunter in baseball to Ham Richardson and Bill Tilden in tennis.

Exercise does pose a potential problem for the insulin-dependent diabetic. The release of insulin from a subcutaneous injection is steady and does not fall off during exercise as it does in the nondiabetic. In fact, if the insulin is injected in an exercise site, such as the leg of a runner, insulin release is markedly enhanced by exercise. This means that the liver will not release glucose into the bloodstream, whereas in the normal person, a decline in insulin levels during exercise triggers the liver to release glucose into the bloodstream. Thus, the release of stored glycogen in the diabetic's liver as glucose in the bloodstream is reduced. This is partially offset by the fact that the diabetic's ability to manufacture glucose is enhanced. However, the net effect is reduced liver glucose output, thus rendering the insulin-dependent diabetic potentially at risk for hypoglycemia or low blood sugar unless he or she either decreases the intake of insulin or increases the intake of carbohydrates before engaging in unusually strenuous prolonged exercise. Most diabetics would find either alternative quite desirable.

Exercise therefore affords a reduction in insulin requirements and a liberalization of carbohydrate intake in the insulin-dependent diabetic. For many people with adult-onset diabetes, exercise can eliminate insulin requirements entirely and return glucose tolerance to normal. In a word, it "cures" the disease.

Well-regulated diabetics have an exercise energy metabolism that is not different in principle from that of similarly trained nondiabetics. Exercise reduces the level of blood sugar by enhancing muscle glucose uptake in diabetics and nondiabetics alike. The insulin receptors in diabetics have been shown to become more sensitive in response to exercise. Thus, even when the level of circulating insulin is extremely low, glucose utilization by muscle and other tissues is increased. This is true in both juvenile and adult-onset diabetes.

Moderate to intense exercise increases tolerance for glucose in both the nondiabetic and the diabetic. This is believed to be the result of the not yet fully understood effects that exercise has on glucose metabolism for as long as 24 to 48 hours after the period of exertion. During this postexercise period, replenishment of muscle and liver glycogen occurs. As compared with the pre-exercise or resting state, a greater proportion of the sugar and starch (carbohydrate) the diabetic eats goes toward replenishing muscle glycogen. Since glucose uptake by muscle and glycogen resynthesis in the muscle and the liver require a minimal concentration of insulin, the diabetic experiences an improvement in glucose tolerance, while insulin requirements are diminished.

Exercise also enhances the utilization of free fatty acids and ketone bodies, as well as glycogen in liver and working muscle.

Insulin is necessary for transporting the building blocks of protein (amino acids) into the muscle. In prolonged starvation and uncontrolled diabetes, the muscle protein, when broken down during exercise, is not replenished, which causes the muscle to begin wasting away. When the disease is controlled, however, increased exercise brings on rapid muscle growth (hypertrophy). Thus, diabetics can engage in every sport, including weight lifting and body building, where increasing muscle bulk is of paramount importance.

The message for the diabetic is loud and clear:

Exercise is mandatory for maximal control of your disease, and daily exercise through sports will very likely retard the development of vascular complications. Your cardiovascular system can become conditioned as quickly as that of the nondiabetic. There is no exercise or sport you should avoid. Your only risk is in developing hypoglycemia with sustained exercise for more than 40 minutes, and your carbohydrate intake and/or insulin administration can be adjusted accordingly. There are diabetics running in marathons and actively pursuing every competitive endurance sport.

Robert C. Cantu

See also Diabetes in the Young Athlete; Exercise and Disease Prevention

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Diarrhea

Diarrhea is generally defined as an increase in the frequency and liquidity of bowel movements. Diarrhea can vary from semisolid to watery and can be classified as *acute* if its duration is less than 4 weeks and *chronic* if it is greater than 4 weeks. Diarrhea and related symptoms such as abdominal cramping and an increased urge to defecate with high-intensity exercise are fairly common; in up to 50% of athletes, these symptoms will occur at least occasionally.

Acute Diarrhea

In healthy athletes, most cases of acute diarrhea are infectious in origin, including viral gastroenteritis, food poisoning, and traveler's diarrhea. Athletes, especially those participating in college athletics, are at higher risk for acute diarrhea due to person-to-person contact with other athletes in locker rooms and athletic training rooms, during practices and competitions, in dormitories and other close living arrangements, and while eating and traveling together. It is not uncommon for infectious diarrhea to spread quickly through a team's players and staff due to this environment.

Acute diarrhea can be caused by viruses, bacteria, and parasites. The leading viral cause of acute diarrhea in older children and young adults is noroviruses (formerly known as Norwalk-like viruses). These viruses are more likely to also cause nausea and vomiting than bacteria and parasites, especially in children. Rotaviruses and Hepatitis A can also cause viral diarrhea. Bacterial causes include *Campylobacter, Escherichia coli, Salmonella,* and *Shigella.* Another bacterial cause is *Clostridium difficile,* which is more likely to occur after the treatment of another infection with antibiotics. *Giardia* and *Entamoeba histolytica* are the most common parasitic causes of diarrhea.

Most cases of acute diarrhea are spread via the fecal-oral route, meaning that the infectious material from the stool is ingested by a new host. The methods by which this can occur include eating food prepared by infected food handlers, sharing eating utensils with an infected person, and eating or drinking contaminated water or food. Another mechanism of acquiring acute diarrhea is eating food that has been improperly prepared or stored (also known as food poisoning).

Symptoms of acute diarrhea include increased frequency and liquidity of stools, abdominal pain and cramping, and sometimes fever, nausea, and vomiting. If the patient has bloody stools, it is suggestive of a bacterial infection. In evaluating patients with acute diarrhea, the history should include questions about what they have eaten recently, whether they have had contact with anyone with similar symptoms, whether they can keep fluids down without vomiting, and how frequently they are urinating. It is also important to ask about travel, camping, or drinking of well or freshwater that has not been appropriately treated. On physical exam, it is important to evaluate for dehydration, assess orthostatic vital signs, and rule out an acute abdomen by checking for peritoneal signs.

Most cases of acute diarrhea are self-limiting and will resolve with just supportive care, so laboratory testing in not done routinely. Reasons for doing laboratory tests include grossly bloody stools, severe diarrhea resulting in dehydration, illness that is not improving after 48 hours, body temperatures greater than 38.5 °C (101.3 °F), severe abdominal pain, and diarrhea in the immunocompromised or the elderly. If further testing is indicated, the usual tests would be stool for fecal leukocytes, stool culture, stool for ova and parasites (three separate samples required), and *Clostridium difficile* toxin if there is a history of recent antibiotic use.

As stated above, most cases of acute diarrhea will resolve with time and supportive management with rest, oral or intravenous hydration, and bismuth subsalicylate (Pepto-Bismol). Antidiarrheal medications are generally not recommended, as diarrhea helps clear the offending pathogen and using medications may help control the symptoms temporarily but might delay full recovery. Athletes with acute diarrhea should be isolated from teammates to prevent its spread to the team and be educated on proper hygiene, such as hand washing.

When traveling to regions with high rates of food-borne disease, athletes and staff should be educated on habits that help avoid traveler's diarrhea. These include avoiding drinking tap water, unpasteurized milk, and iced drinks; eating food only when it is piping hot; and avoiding raw vegetables and fruits that cannot be peeled. Prophylactic treatment with antibiotics is not recommended for most travelers, but athletes and staff are often included in groups for which preventative treatment should be considered. Prophylactic treatment generally consists of bismuth subsalicylate twice daily and a fluoroquinolone antibiotic once daily.

Exercise-Induced Diarrhea

High-intensity exercise, especially long-distance running and other endurance activities, are a frequent cause of diarrhea, abdominal cramping, and an urge to defecate, also known as "runner's trots." There are a number of mechanisms that have been suggested to explain this phenomenon. One favored hypothesis is gut ischemia, caused by the shunting of blood flow away from the gastrointestinal (GI) tract to the cardiovascular and muscular systems. This can be exacerbated by dehydration. Another theory is that exercise increases the amounts of circulating catecholamines, such as epinephrine and norepinephrine, and other peptides with activity in the GI tract, such as gastrin, motilin, secretin, and vasoactive intestinal peptide, resulting in an increased transit speed of the intestinal contents. Another suggested mechanism is stimulation of the gut by the bouncing and vibrations from prolonged exercise.

The evaluation of an athlete with diarrhea caused by exercise is focused on determining if there is an underlying cause for the symptoms, as exercise-induced diarrhea is a diagnosis of exclusion. Some authors have called exercise a "stress test for the GI tract," and exercise may reveal an otherwise asymptomatic or mildly symptomatic GI condition. History and exam should concentrate on findings suggestive of irritable bowel syndrome, lactose intolerance, hyperthyroidism, parasitic infections, antibiotic use, exercise-induced anaphylaxis or urticaria, laxative abuse (seen in athletes competing in sports with weight classes and those with female athlete triads), and inflammatory bowel disease. Additional testing would include the tests mentioned above in the evaluation of acute diarrhea and flexible sigmoidoscopy or colonoscopy, especially in athletes over the age of 40, who have a higher risk of colon cancer.

Once other conditions have been ruled out, treatment of exercise-induced diarrhea should include attempting to have a bowel movement before exercise, maintaining proper hydration, and avoiding caffeine (a GI stimulant), nonsteroidal anti-inflammatory drugs (NSAIDs), and high-sugar beverages 2 to 3 hours before exercising. Symptoms also tend to improve as fitness increases; so, over time, symptoms may gradually resolve with continued training. Excess dietary fiber should also be avoided. Antidiarrheal medications, such as loperamide, can decrease sweating, so most authors recommend avoiding them, but they can be used in cases with a history of extreme urgency resulting in soiling.

Michael Stump

See also Travel Medicine and the International Athlete

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Dietary Supplements and Vitamins

Athletes often seek dietary supplements to enhance performance. A *supplement* is a substance added to the diet to make up for a dietary deficiency or to enhance the diet and possibly athletic performance. In ideal circumstances, supplements should not be used as a substitute for an optimal diet. This entry provides an overview of some popular performance-enhancing supplements.

Products that are classified as vitamin and mineral supplements are required to meet U.S. Food and Drug Administration (FDA) standards, while those supplements classified as simply "dietary supplements" are not. In addition, supplements are not required to meet the same safety requirements as over-the-counter or prescription drugs or food ingredients. Furthermore, they are not held to specific manufacturing standards that would guarantee the purity or potency of the product. Finally, the FDA is prohibited from removing a product from the market unless it can prove that the product poses a health risk. Thus, most health risks of supplements are discovered after the product has been on the market and has caused health problems.

Supplements may be classified as those derived from macronutrients (protein, carbohydrate, and fat) or micronutrients (vitamins and minerals), and herbal-based products. The following sections outline some common supplements.

Fats

Medium-chain triglycerides (MCT) contain fatty acids that are shorter in length than most fatty acids and, thus, are absorbed more rapidly. Some of the potential benefits of MCTs are that they are a readily available energy source, are sparing of lean body mass, increase the metabolic rate, are sparing of glycogen, and increase fat use for fuel. However, several studies assessing MCTs and performance have found no benefit for endurance or strength.

Omega-3 fatty acids are a group of unsaturated fatty acids that cannot be synthesized by the human body and are thus essential to consume in the diet. Potential benefits of omega-3 fatty acids include reduced muscle soreness, improved blood flow and nutrient delivery, improved aerobic metabolism, reduced inflammation, and improved muscle recovery. However, numerous studies show no evidence of any performance benefits from omega-3 fatty acid supplementation.

Conjugated linoleic acid (CLA) is part of a group of unsaturated fatty acids found in beef, lamb, and dairy products. Performance claims include fat loss and increased strength and muscle mass. Studies in humans are mixed, with some reporting a significant decrease in body fat and others reporting no significant changes in body fat, strength, muscle mass, or fat oxidation. There have been no adverse effects of CLA supplementation. Further research on performance benefits is warranted.

Proteins

Branched-chain amino acids (BCAA) are a group of essential amino acids designated by their branched structure. They include leucine, isoleucine, and valine. During prolonged exercise, BCAA may play a role in delaying central nervous system fatigue, be used as an energy source, and prevent immunosuppresion. However, studies are mixed, and supplemental BCAA have not been shown to improve performance or delay fatigue, although positive effects have been reported in studies examining immune response during prolonged exercise.

Glutamine is a conditionally essential amino acid and can be synthesized by the body under normal conditions. Under physiologic stress, glutamine may be needed at higher rates than the body is able to synthesize, and supplementation may therefore be beneficial. Benefits may include decreased exercise-induced stress, improved recovery, decreased muscle catabolism, and increased muscle mass. However, study results have been mixed, with some evidence of enhanced immunity and other evidence suggesting no performance, body composition, or immune benefits.

Arginine is another conditionally essential amino acids. Arginine functions in protein synthesis and in the detoxification of ammonia and plays a role in the production of other biologically active compounds. Arginine may increase growth hormone secretion and the synthesis of creatine and nitric oxide.

Carbohydrates

Glycerol is a 3-carbon sugar alcohol used as a carbohydrate-like fuel. Glycerol may benefit athletes exercising in hot and humid environments by helping them retain extra water. However, there is also evidence of significant side effects. At high doses, glycerol supplementation appears to cause headaches, dizziness, nausea, and a predisposition to hyponatremia.

Pyruvate is a 3-carbon compound produced by the metabolism of sugar. It has been suggested that supplementing with pyruvate may increase aerobic endurance and decrease body fat. Studies have found no evidence of enhanced aerobic performance or of fat loss. Also, severe adverse gastrointestinal effects have been reported with high pyruvate doses.

Vitamins

Vitamin E is a powerful antioxidant. Athletes are subject to increased oxidative stress from exercise. Thus, the potential benefits of supplemental vitamin E for better aerobic performance, greater strength, and reduced oxidative damage have been studied. Evidence suggests no performance or strength benefits, but vitamin E may prevent oxidative damage. Good sources of vitamin E include plant oils, nuts, seeds, and wheat germ.

Vitamin B_6 is a water-soluble vitamin necessary for protein and energy metabolism. Inadequate vitamin B_6 levels have been linked to decreased athletic performance; thus, exercise may increase the need for vitamin B_6. Adequate vitamin B_6 may be consumed in a balanced diet; therefore, supplementation is generally not necessary. Good sources of vitamin B_6 include liver, chicken, bananas, potatoes, and spinach.

Thiamin is a water-soluble vitamin particularly important for carbohydrate energy metabolism. Athletes who consume high-carbohydrate diets must also consume appropriate amounts of thiamin or performance may be diminished. Studies have found no benefit of thiamin supplementation above the recommended levels. Good sources of thiamin include peanuts, wheat germ, green peas, collard greens, oysters, liver, and nutritional yeast.

Vitamin B_{12} is a water-soluble vitamin important for DNA (deoxyribonucleic acid) synthesis, red blood cell formation, and nerve development. B_{12} injections are commonly given to athletes before competition; however, there is no benefit of B_{12} above the recommended levels. Supplementation of vitamin B_{12} may be appropriate for vegan athletes, who are commonly deficient. Good sources of vitamin B_{12} include fish, dairy products, beef, eggs, poultry, and fortified cereals.

Niacin is a water-soluble vitamin involved in energy production from carbohydrate, fat, and protein. There is some evidence that niacin supplementation may facilitate the regulation of body temperature in athletes. However, other studies have reported negative effects with niacin supplementation, including reduced endurance due to altered fuel metabolism. There is no evidence that niacin requirements increase with exercise; thus, supplementation is not necessary given an adequate intake. Good sources of niacin include beef, pork, chicken, eggs, milk, and wheat flour.

Vitamin C is a water-soluble vitamin that functions as an antioxidant. It is also important for connective tissue synthesis, formation of neurotransmitters, and generating energy from fatty acids. Vitamin C needs may be increased for athletes, especially those participating in endurance events. The increased requirement of vitamin C may be met through food; thus, supplementation is generally not necessary. Good sources of vitamin C include citrus fruits, kiwis, broccoli, Brussels sprouts, and red or green peppers.

Minerals

Phosphorus is a mineral required in bone formation, and it also plays a role in energy metabolism. "Phosphate loading" is a strategy used by some athletes to decrease the accumulation of hydrogen ions and to delay fatigue. However, there is limited evidence of performance improvement with high phosphorus intake. Furthermore, there may be long-term consequences of excessive phosphorus intake as it may decrease bone density. Good sources of phosphorus include milk, cheese, yogurt, nuts, oatmeal, and asparagus.

Potassium is a mineral and the main electrolyte found in cells. It is important for muscular contraction, nerve impulses, and water balance. Potassium lost in sweat does not typically have an impact on performance in a well-nourished athlete. Good sources of potassium include oranges, bananas, potatoes, tomatoes, and blackstrap molasses.

Iron is a mineral necessary to form oxygen-transporting proteins in blood and muscle. Iron deficiency has been shown to have detrimental effects on exercise performance. Female athletes commonly have some degree of iron deficiency due to increased needs. Iron supplementation may be warranted for athletes with any form of iron depletion. However, excessive iron supplementation has not been shown to be beneficial and may even lead to iron overload disease. Good sources of iron include red meat, oysters, egg yolks, tofu, whole grains, salmon, and raisins.

Herbals

Chinese ginseng (*Panax ginseng*) is a plant that has been used for centuries in Asian cultures to help reduce fatigue, increase vitality, improve health, and attain longevity. Results from the scientific literature investigating Chinese ginseng and athletes show no clear improvement in performance. However, there is limited evidence of greater benefits in older individuals (>40 years) and if taken at a sufficient dosage for a sufficient period of time (>8 weeks).

Tribulus terrestris (puncture vine) is frequently used as a medicinal tonic and dietary supplement. Benefits of tribulus supplementation may include increased testosterone production, mood enhancement, elevated sex drive, and strength and muscle gains. Despite these claims, several studies looking at tribulus supplementation in athletes have found no elevation in testosterone, reduction in fatigue, or changes in strength and body composition.

In summary, supplementation may be beneficial for athletes and depends on the diet as well as on sport-specific requirements. Seeking advice from a trained professional is recommended.

Jan Pauline Hangen

See also Dietitian/Sports Nutritionist; Nutrition and Hydration

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Dietitian/Sports Nutritionist

With the expansion of professional sports franchises and the increasing number of Olympic sports, the participation of elite athletes today is on the rise. Healthful nutrition is important throughout the life span, because suboptimal nutritional status may impair training and sportive performance. Appropriate nutrition during training is one of the key elements for success in a competition. Increased energy expenditure during training needs the enhancement of caloric intake to maintain body weight, and an addition of 500 to 1,000 calories or more per day is needed in certain activities. The consumption of a wide variety of foods is necessary for these additional caloric needs. Adequate amounts of all nutrients essential for the formation of new body tissues and for the proper functioning of the energy systems should be considered. A balanced intake of carbohydrate, fat, protein, vitamins, minerals, and water is all that is necessary.

Sports nutrition is an established discipline that specializes in the nutrition of athletes. A good command of general nutrition and exercise science, an understanding of their interrelationship, and the knowledge of how to practically apply sports nutrition concepts are needed in applied sports nutrition.

If two athletes are equally talented, equally well trained, equally motivated, and equally well coached, good nutrition can make the difference. Good nutrition will optimize performance. Athletes need to consume nutrients in proper amounts, but specialized knowledge is needed to develop an appropriate nutritional strategy. Good health should be the main goal, without which the best performance will not be achieved. A sport nutritionist, who is able to provide an appropriate and well-fitting nutritional plan, is essential in a sports team.

Sports nutrition is the application of knowledge of nutrition to create a daily eating plan, which focuses on providing fuel for training, enhancing the repair and rebuilding process of strenuous physical work, optimizing performance in sportive events, and promoting overall health and wellness. The term *athlete* includes not only elite athletes; it also refers to any individual who is regularly involved in sports activities.

The primary responsibility of a sports dietitian is the counseling of individuals and groups on daily nutrition for performance and health. This involves translating the latest scientific evidence into practical recommendations; tracking and documenting the outcomes of nutrition interventions; serving as a food and nutrition information resource for athletes, trainers, and parents; and providing sports nutrition education. .

The following services are provided by the sports nutritionist:

Individual Nutrition Counseling

- Evaluating athletes' diet, body composition, and energy balance to improve athletic performance and health
- Providing counseling about optimal nutrition to enhance training goals, competition, disordered eating, travel, and supplementation
- Helping athletes achieve and maintain body weight (body mass, body fat, and muscle mass)
- Controlling the hydration status of athletes
- Considering the medical problems of athletes (food allergies, bone mineral disturbances, gastrointestinal disturbances, iron depletion, and iron deficiency anemia, etc.)
- Coordinating nutritional care as a member of multidisciplinary sports teams
- Evaluating nutritional supplements for legality, safety, quality, and efficacy
- Counseling for the appropriate use of supplementation
- Counseling athletes' families, physicians, trainers, and other health professionals
- Developing educational materials and providing training (e.g., in food selection and preparation)
- Developing and supervising nutrition policies and procedures

Food Service and Menu Development

- Coordinating/managing food production, training table menus, and catering
- Coordinating nutrition for domestic and/or international travel
- Managing budgets for nutritional supplements
- Planning dietary menus for the table and for travel
- Suggesting pre-, during-, and postexercise fluids and snacks

Nutrition Education for Teams, Groups, or Wellness Programs

- Providing educational presentations on various nutritional topics for sportive performance
- Providing resources for trainers, teachers, food service staff, and parents
- Providing nutrition education for food service staff

Professional Development

- Managing registration and continuing-education activities
- Keeping up to date on nutritional issues and research related to sports nutrition

Appropriate selection of foods and fluids, intake timings, and choice of supplements are recommended by a position paper of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine. During times of high physical activity, sufficient intake of carbohydrates and proteins is warranted, and fat intake should provide essential fatty acids and fat-soluble vitamins. Energy from fat should be at least 20% to 25%, and adequate food and fluid consumption could help optimize sportive performance, improve recovery time, and prevent decrease of blood glucose. Hydration of athletes before and after exercise is also highly recommended. Careful reviewing of the athlete's health, nutritional status, and drug use and energy requirements is required, and nutritional advice should be provided by a sports nutritionist whenever possible.

Neşe Toktaş and Hakan Yaman

See also Nutrition and Hydration

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Diffuse Axonal Injury

Sports-related closed-head injuries essentially follow the same clinical spectrum as is seen in nonathletic closed-head injuries. Injuries range from the common *cerebral concussion*, a form of mild traumatic brain injury (TBI), to the most severe, *diffuse axonal injury* (DAI). Though severe closed-head injuries are relatively rare in organized athletics, occasionally tremendous force transfers will occur between players involved in a collision. The impact can result in massive structural damage to the brain, clinically manifested as prolonged loss of consciousness or even coma.

Epidemiology

In DAI, the outcome is rarely death, but frequently it is coma. Up to 90% of patients with severe DAI remain in a persistent vegetative state. Those patients who do wake up often remain profoundly impaired. DAI has hence been found to be the most significant cause of morbidity in patients with TBI. With its high degree of chronic debilitation, DAI potentially becomes a highly stressful family problem exacerbated by staggering medical costs.

Anatomy

The brain has three main components: the cerebrum, the cerebellum, and the brainstem. The cerebrum comprises a left and right hemisphere connected by a large bundle of nerve fibers, the corpus callosum. The cerebral hemispheres are divided into lobes corresponding to the section of the overlying skull: temporal, parietal, and occipital. The cerebellum and brainstem are located posterior and inferior to the cerebral hemispheres.

Brain tissue consists of 40% gray matter and 60% white matter. Gray matter is dark in color because of the relatively high proportion of nerve cell nuclei present. White matter consists mostly of axons covered with lightly colored myelin, an insulating protein sheath. Brain cells include neurons and glial cells. Glial cells make up 90% of the brain cells and exist to provide essential support functions to neurons. Neurons are nerve cells that send and receive electrochemical signals to and from the brain and the distal nervous system. Each consists of a cell body with branching dendrites (signal receivers) and a long projection called an axon, which conducts the nerve signal. Bundles of axons called nerves are in the body's periphery and are referred to as *nerve tracts* within the central nervous system.

Primary Injury

As the name suggests, DAI is a widespread insult to the brain axons, in contrast to a focal brain injury such as a contusion, laceration, or hematoma. The injury is the result of traumatic shearing forces that typically occur when the head is subjected to rapid acceleration/deceleration or severe rotational forces. Motor vehicle accidents are the most frequent cause of DAI. Severe DAI is almost always due to vehicular injury. DAI has been documented in practically every sporting event that potentially involves a sudden head deceleration from a high-speed collision with an immovable object.

The major cause of damage in DAI is the disruption of axons through shear injury. *Shear injury* refers to the damage sustained to brain matter as tissues of varying density slide over each other in response to forces produced in a sudden acceleration/deceleration impact. Axonal tissue disruption is greatest in those areas where the density difference is greatest. For this reason, the majority (two thirds) of DAI lesions occur at the gray/white-matter junction. The regions of the brain most commonly injured are the frontal and temporal lobes, followed by the corpus callosum. The DAI affecting the corpus callosum is more frequently unilateral and may be hemorrhagic due to close proximity to blood vessels. Consequently, the involvement of the corpus callosum carries a relatively poor prognosis. The brainstem typically remains unaffected, which helps explain why DAI rarely causes death.

Secondary Injury

DAI was traditionally believed to be the result of primary injury—that is, the mechanical forces absorbed at the time of impact. It is now understood that a series of secondary biochemical processes, which occur in response to the primary injury, are largely responsible for the axonal injury. The precise nature of these processes has not been fully elucidated to date, but the essential microscopic characteristic of DAI has been determined to be axonal separation. Specifically, the injury cascade is triggered on impact by shear forces, which cause an axonal disruption or tear. This results in misalignment of the cytoskeletal elements in the axon and impairment of nerve product (neurotransmitter) transport. These transport products rapidly accumulate and cause a local swelling that, once it is large enough, triggers a split of the axon into two pieces. The injured axon then draws back toward the cell body and forms what is known as a retraction ball. This retraction ball is the pathologic hallmark of DAI. The portion of the axon distal to the tear will degrade and eventually die. The earliest signs of this secondary injury process are seen beginning 4 hours after the primary impact, but it may continue to evolve over days to weeks.

Because axonal damage in DAI is ultimately the result of secondary biochemical processes of delayed onset, the head-injured athlete, who initially appears to be well, may deteriorate later. This is because the injury is frequently more severe than initially realized. The examining physician should have a high index of suspicion for DAI in any patient whose brain CT/MRI (computed tomography/magnetic resonance imaging) scan appears normal but who has obvious symptoms of severe head trauma, for example, unconsciousness. The degree of microscopic injury is typically higher than visualized using current imaging techniques, and the clinical presentation tends to reflect this point.

Clinical Spectrum

DAIs have a wide spectrum of severity, ranging, like cerebral concussion, from mild to severe. The clinical presentation depends primarily on the extent and location of axonal disruption. DAI commonly results in instantaneous loss of consciousness, and greater than 90% of patients experience profound and prolonged impairment of neurological function, typically manifested in a persistent vegetative state. The chance that a patient will continue to remain in this state is greater when axonal lesions are observed in the cerebral white matter and corpus callosum. The prognosis worsens as the number of lesions increases, especially if it is associated with hemorrhage.

Diagnostic Imaging

Although 50% to 80% of DAI patients have a normal CT scan on presentation, 80% will eventually demonstrate multiple areas of injury on CT scan. Severe cases of DAI exhibit characteristic features on CT scan in the acute setting, most notably small hemorrhages, less than 2 centimeters in diameter, located in the cerebral hemispheres at the gray/white-matter junction, as well as the in the corpus callosum. An abundance of DAI lesions in the corpus callosum can result in deficits of information transfer between the two sides of the brain, resulting most often in hearing deficits. In the setting of DAI without coma, the injury often results in neuropsychological impairment dominated by executive and memory dysfunction. For the nearly 10% of patients who experience a return to any form of normal function, this improvement will be seen within the first year.

An MRI scan is more sensitive than a CT scan and is the preferred method of imaging for DAI. However, CT scanning is more easily available and practical in emergency settings, and it remains a vital tool in the acute investigation of head injury. In an acute setting where DAI is suspected clinically yet CT scan findings are negative, MRI is then considered, as it may demonstrate lesions not visualized through CT scanning. It has been discovered that MRI can be used to reliably assess and quantify the volume of white matter lesions resulting from DAI. In general, patients with greater DAI volume have poorer functional outcomes. Along these lines, MRI may be useful in stratifying injury severity and may possibly play a role in predicting the duration of coma in DAI patients.

Sports-Related Injury

From a sports medicine perspective, DAI most commonly occurs in motor sports, where closed-head injuries account for the vast majority of head injuries. Motor sports aside, the injury is occasionally seen in severe athletics-related head trauma. Of note is a recent study that asked whether the location of impact influenced DAI patterns. It was found that the likelihood of DAI increased 11-fold in patients sustaining a lateral impact (vs. frontal and oblique). When DAI is associated with an open-head injury in motor sports, the outcome is always catastrophic. However, DAI accounts for less than 5% of all closed-head injuries in motor sports, in large part due to strictly instituted safety measures. These include restraining the helmeted driver with a shoulder harness into a safety cell within the vehicle, which itself is designed to dissipate the forces of a crash. In addition, professional motor sports mandate the immediate presence of emergency medical providers. All told, these measures have resulted in several examples of complete recovery from mild to moderate DAI, with some of the drivers able to return to competition following a period of rehabilitation. This is an exception, however, because for the majority of athletes who sustain DAI, complete neurologic recovery is uncommon; hence, return to a collision or contact sport is usually not a realistic goal.

It must be stressed that the major difference between athletic and nonathletic head injury is that the injury to the athlete is often preventable. DAI currently lacks a specific treatment protocol beyond what is typically followed for severe closed-head injury, including limiting increases in intracranial pressure. Cognitive rehabilitation can be beneficial. On a microscopic level, research has demonstrated that dendritic restructuring might occur, with some regeneration possible in mild to moderate injury.

Adam E. Perrin

See also Concussion; Head Injuries

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Discoid Meniscus

Discoid meniscus is a term used to describe an abnormally block-shaped and potentially loose meniscus in the knee joint. It is believed to be a congenital condition present at birth. It occurs in approximately 5% of the population, and 25% of the time it occurs in both knees. In many cases, it does not cause symptoms; however, in some young children, it can cause “snapping knee” syndrome. In older children, a discoid meniscus can tear after an injury to the knee. A discoid meniscus that is very loose or that tears may require surgery.

Anatomy

A *meniscus* is a shock absorber cushion that sits between the cartilage of the femur (thighbone) and the cartilage of the tibia (shinbone). Each knee has two menisci—a medial (inner) meniscus and a lateral (outer) meniscus. A discoid meniscus occurs in place of the lateral meniscus 97% of the time. The normal lateral meniscus is crescent shaped when looked at from above, with the opening of the crescent facing the center of the knee. The normal lateral meniscus is also shaped like a wedge from the front, so that the crescent tapers toward the center of the knee joint. A discoid meniscus resembles a complete circular disc instead of a crescent from above and is block shaped (i.e., it does not taper toward the center of the knee). In addition, the normal lateral meniscus is properly anchored to the tibia and femur by ligaments so that it is stable inside the knee. A discoid lateral meniscus may lack these attachments and may be very loose within the knee.

Causes

It is unclear what causes a discoid meniscus. A discoid meniscus is currently believed to be a congenital malformation and not a developmental variant, because a normal meniscus never resembles a discoid meniscus during its development. One theory is that when a developing meniscus does not form proper attachments to the tibia and femur, it is very loose, and to compensate for this instability, it develops discoid features, such as being circular and block shaped.

Symptoms

Many people with a discoid meniscus never have any symptoms. It is likely that in these cases, the discoid meniscus is properly attached and not loose. Young children who have a discoid meniscus that is not properly attached to the knee present with "snapping knee" syndrome. In these cases, the child experiences episodes of dramatic snapping and popping in the knee. These snaps occur spontaneously as the knee straightens and usually produce temporary pain and apprehension. In very young children (between the ages of 3 and 4), the snapping may be audible but is usually painless. The snap represents the loose discoid meniscus moving more than it should inside the knee. Older children with a discoid meniscus that is properly attached often do not have any symptoms unless they injure their knee. These patients have a higher risk of tearing their discoid meniscus after a trauma. They present with pain and swelling on the outer aspect of the knee after a knee injury.

Diagnosis

A history of snapping inside the knee in a young child should alert the practitioner to evaluate for a discoid meniscus. On physical exam, the clinician should feel for a dramatic clunk on the outer aspect of the knee as the knee is flexed and rotated (McMurray test). Sometimes a bulge may be visible on the outer aspect of the knee with knee flexion. The clunk and bulge likely represent an unstable discoid lateral meniscus. Because discoid menisci occur in both knees 25% of the time, the other knee should be carefully examined as well.

A discoid meniscus is not visible on X-ray. However, secondary changes such as squaring of the femur can be seen on X-ray, suggesting the possibility of a discoid meniscus. When a discoid meniscus is suspected, a magnetic resonance imaging (MRI) scan should be performed. The MRI scan will often show the block-shaped, circular appearance of a discoid lateral meniscus.

In some cases, the meniscus may only be partially discoid in shape but still lack proper attachments. These are termed *incomplete* or *partial discoid menisci,* and often they appear normal on an MRI scan. Therefore, the gold standard for diagnosing a discoid meniscus is knee arthroscopy. Arthroscopy allows the surgeon to directly visualize the meniscus and to probe it to test its stability. Discoid menisci are usually classified based on their appearance (complete, disc shaped or incomplete, crescent shaped) and their stability (stable or unstable to probing).

Treatment

Treatment of a discoid meniscus depends on the patient's symptoms and the stability of the meniscus. A stable discoid meniscus that does not cause pain is usually just observed over time. A young child with a snapping knee that does not cause pain also does not require surgery. Physical therapy is often recommended for these patients to strengthen the knee. Surgery is reserved for patients with a discoid meniscus who develop pain, swelling, locking, or catching of the knee. These symptoms suggest that the meniscus is unstable and is prone to tearing or has already torn. In some patients, a discoid meniscus is incidentally discovered on an MRI scan or during knee arthroscopy for another reason. If these patients do not have any symptoms related to their discoid meniscus, no specific treatment is recommended.

Surgery

Surgery is recommended for most discoid menisci that cause symptoms. A discoid meniscus is most commonly treated with knee arthroscopy. During arthroscopy, the surgeon will view the meniscus to determine if it is a complete or incomplete discoid meniscus, using a small arthroscopic probe to test its stability and carefully looking for any tears in the meniscus. Depending on these findings, the surgeon will decide how to proceed.

In the case of a complete discoid lateral meniscus, most surgeons will first attempt to reshape the meniscus. This process is termed discoid *saucerization,* and it is done using small arthroscopic instruments to cut away the central portion of the disc-shaped meniscus so that it resembles a more normal crescent shape. This treatment represents a recent change in the management of discoid menisci. In the past, when a discoid meniscus was encountered during surgery, most physicians removed the entire meniscus (termed *total meniscectomy*). As we have come to understand the importance of the meniscus as a shock absorber, many physicians now favor saucerization (or *partial meniscectomy*), as opposed to complete excision. The idea is to preserve the crescent-shaped part of the meniscus so that the meniscus can maintain part of its shock-absorbing function after surgery.

Following saucerization, the surgeon will carefully assess the stability of the remaining meniscus. If the discoid meniscus is lacking proper attachments, it will be abnormally loose when assessed with the arthroscopic probe. In these cases, the meniscus must be reattached to the knee capsule in the area where it is not properly attached. The process is called meniscal repair and can be done using small instruments to place sutures across the meniscus and into the capsule surrounding the knee.

In some cases, a tear may be noted in the discoid meniscus itself. Depending on the appearance and location of the tear, the surgeon will decide how to proceed. If the tear is in the central portion of the meniscus, which would normally be cut away during saucerization, then the surgeon will just remove the tear during this process. If the tear is in the part of the meniscus that remains following saucerization, the surgeon can elect to repair the tear with meniscal sutures or selectively remove the portion of the meniscus containing the tear.

After Surgery

Following knee arthroscopy, crutches are necessary for a few days while pain and swelling of the knee are present. If the patient has undergone saucerization only (without meniscal repair), the knee is allowed to move without a brace, and the patient can then be weaned from crutches as soon as possible. Physical therapy is usually necessary for 6 weeks, after which the patient is allowed to return to full activities. If a meniscal repair was performed, a brace is often used to limit motion, and crutches may be necessary for 4 to 6 weeks. Return to full activity following a meniscal repair occurs after a course of physical therapy at about 3 to 4 months after surgery.

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See also Arthroscopy; Knee Injuries; Meniscus Injuries

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Diuretics

Diuretics are a group of medications typically used to treat high blood pressure or congestive heart disease, but they have also been abused by athletes to gain a competitive advantage or to cover up evidence of the use of other performance enhancers.

A *diuretic* is anything that causes a person to produce more urine from the kidneys. There are many different kinds of diuretics, and they act on the kidney in slightly different ways. Medications such as hydrochlorothiazide (HCTZ) or furosemide affect the small blood vessels in the kidney. This changes how blood flows through the kidney and causes more free water to be filtered from the blood. Osmotic diuretics such as mannitol work in a different way. Free water is drawn out of the blood by the kidneys by way of elaborate concentration gradients, producing very dilute urine very quickly.

As urine is produced, electrolytes and minerals are lost in the urine. In addition, toxins and chemicals are cleared from the body. The athlete also loses free water from the blood. Diuretics are commonly used in medicine to treat high blood pressure or congestive heart failure. During this treatment, electrolytes such as potassium and sodium are carefully monitored and sometimes have to be supplemented.

Diuretics are used for therapeutic purposes and can be abused for enhancing athletic performance. Athletes may surreptitiously use diuretics for several reasons. Wrestlers and boxers use them to rapidly lose weight so they can compete in a specific weight class. Bodybuilders use them before the competition to dehydrate themselves and enhance muscle definition. Diuretics are sometimes used by athletes who are trying to cover up the use of other performance-enhancing substances and beat a drug test. This is one of the reasons why drug testing in sports includes tests for the presence of diuretics. The presence of some of these diuretics in a drug test is considered as grounds for disqualification unless a documented medical reason for using the diuretic is presented to the competition committee prior to the event.

There is a process, however, to ensure that an athlete is able to use a substance that could be otherwise considered a doping agent, such as insulin or albuterol, in a medically responsible way to treat an illness or condition. A Therapeutic Use Exemption is not valid if an athlete's urine contains a diuretic in association with threshold or subthreshold levels of a prohibited substance.

There can be significant side effects from the use of diuretics. Rapid shifts in electrolytes can cause deadly heart arrhythmias or seizure. They can cause dehydration and symptoms such as dizziness, fatigue, confusion, headache, or syncope (passing out). In addition, electrolyte abnormalities and dehydration can contribute to muscle cramping and worsening of asthma symptoms. Dehydration and diuretic use can contribute to kidney damage and renal failure.

Michael O'Brien

See also Doping and Performance Enhancement: A New Definition; Doping and Performance Enhancement: Historical Overview; Doping and Performance Enhancement: Olympic Games From 2004 to 2008

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Diversity in Sports

Traditionally, discussions of diversity have focused on race, gender, age, religion, disability, and sexual orientation. It should also be noted that *diversity* can also encompass socioeconomic background, affiliated socioeconomic conditions (e.g., education, location), and marital status. What does diversity mean for sports and athletics? It fosters the promotion of the uniqueness of individuals as they demonstrate their skills and abilities in sports. Diversity is the basis for the provision of equitable opportunities for all individuals to participate in sports and athletics (with or without modifications), whether it be as athletes, coaches, training staff, or administrators.

Diversity in athletics benefits the individual athlete, the team, and the community, providing exposure to people of different cultures and experiences. In addition, sports diversity can improve team performance and increase productivity as well as decrease team attrition and provide an attractive variety to sponsors of athletic teams and events. Diversity in sports can also foster commuting and cooperation and understanding between countries. One major example is the modern Olympic Games, which were founded on a culture of seeking excellence and promoting tolerance and cultural diversity and exchange. The International Olympic Committee (IOC) expects and demands respect for individuals of all cultures, races, sexes, and abilities. As a complete review of diversity in sports is beyond the scope of this entry, the entry will briefly review some of the major moments pertaining to diversity in sports in the areas of gender, race, and disability, as well as briefly touching on the participation of children and senior citizens in sports and athletics.

Gender and Sport

As men have been freely able to participate in sports throughout history, most discussions of gender diversity and sports focus on women's issues. In the ancient Olympic Games, women were banned not only from participating but also from watching the games—because men competed in the nude. Women first participated in the modern Olympic Games in 1900, at the time of the second Olympiad, but in golf and tennis only. Throughout history, sports-minded women were generally hampered by social and cultural norms, such as having to be "ladylike," and, thus, were discouraged from participating in sports that did not support wearing a skirt.

American women were similarly held back from participation in organized sports. Throughout much of American history, women were considered the weaker sex and discouraged from participating in sports, due to the unladylike activities as well as to an unfounded concern for the reproductive health of the participants. Although not in formal sports, women did participate in athletic activities, such as the early Native American religious dancing and physical contests in worship. Settler women maintained their athleticism, participating in activities of daily living, such as sailing and fishing, as well as in more recreational fitness activities, such as dancing and racing. With the development of modern sports in the 1800s (mostly designed for men by men), women gradually increased their participation in organized sports. By the end of the 19th century, sports for women became more formalized, organized by employers for physical fitness or arranged by various sporting clubs.

Owing to the medical establishment's concern for their reproductive health, women's formal sports and athletic education lagged behind women's sports and athletic participation. Amateur and professional sports clubs, leagues, and competitions were steadily increasing in number, although with varying degrees of success and longevity. One more notable example was the All-American Girls Baseball League during World War II. Women's teams, with the help of runners such as Wilma Rudolph, also began to integrate around World War II. After the feminist revolution of the 1960s, as well as due to the social changes of the time, the state of women in sports would change for all time with Title IX of the Education Amendments of 1972.

Title IX required equity in sports opportunity, equipment, funding, and playing time within any educational institution receiving federal funds. Since Title IX, high school women's sports participation is nearly 10 times what it was in 1971. College women's sports participation has tripled, and there are also an increasing number of sports available to women, including rugby, weight lifting, triathlons, and professional basketball leagues. Women have also increased their participation in men's athletic activities, including high school football, high school baseball, and high school wrestling. Although not as much as men, female athletes have also achieved greater status in American culture. In the same manner as it benefited nonminority women athletes, Title IX also benefited female athletes of color. We must remember that although significant gains have been made, opportunities for male athletes are still greater than for female athletes throughout the sports arena and especially in areas of power and decision making.

Title IX has also decreased the effects of homophobia in sport. Although not specifically written for this purpose, Title IX has been used to address discrimination based on gender stereotypes and sexual orientation (i.e., not masculine enough = gay; a too athletic woman = lesbian). Addressing homophobia, whether or not with the use of legislation, can not only challenge stereotypes but also improve team chemistry and performance and decrease the incidence of suicide, hate crimes, and other destructive behavior.

Race, Ethnicity, and Sport

The term *race,* initially used in the mid-1800s by cultural scientists, was meant as a small and insignificant descriptor of different people. Though many would eloquently and publicly rebut the degradation of the word, over time *race* developed its pejorative nature, creating an artificial hierarchy of betters and lessers. The topic of race and race relations in America is often used to describe two groups: (1) black Americans (i.e., African Americans) and (2) white Americans (i.e., Caucasian Americans). Racial inequality in America, however, led to the struggles of many different groups, in addition to the two above. Slavery and indentured servitude affected the Native Americans, Asian Americans, Latin Americans, and other nonwhite ethnic groups. Discrimination, as it was for blacks, was also legalized for Asian Americans with the Chinese Exclusion Act of 1882 and for other ethnic groups with the National Origins Act of 1924.

Just as the definition of race was not straightforward, so too has been the struggle for equality. Rights and freedoms for all Americans have been gradually granted in multiple constitutional amendments and laws throughout our nation's history. For example, the post–Civil War Reconstruction Period created laws allowing blacks and whites to be "separate but equal." Unfortunately, this doctrine failed and degraded to simply "separate," and segregation, from birth to death, pervaded society until the mid 20th century. Sports, a microcosm representing society, was equally affected.

African Americans have been participating in athletics and athletic activities since colonial times. A fair portion of that participation was either as individual athlete (e.g., in track-and-field events or in boxing) or in a separate league (e.g., the Negro Baseball League from the 1880s to the 1960s), although there were some notable exceptions. With the success of black athletes, like Jack Johnson, a heavyweight boxing champion, in the early 1900s, some football teams attempted integration. These efforts failed, largely due to economic factors, as the Great Depression affected supporting monies. Many professional sporting teams would, however, conduct preseason and postseason games and series with black teams, during which many noticed that the competitive level of the non–Major League teams was high. This "barnstorming" provided an initial venue for black athletes to be seen by an integrated audience.

Major League Baseball was the first organized professional league to integrate successfully. One man hailed for helping to break the color barrier in baseball is Jackie Robinson. Jackie Robinson, the first African American noted for playing on an integrated professional baseball team, joined the Brooklyn Dodgers in 1947. This landmark moment started the tidal wave of American baseball integration. Although not without opposition, from within his own team, from general spectators and Dodger fans, and from opposing teams, Robinson persevered in adversity and went on to become the Rookie of the Year in 1947. Robinson was quickly joined by Satchel Paige, Hank Aaron, and Willie Mays—all praised for their skill in the game. Within the next 12 years, integration in American baseball was complete. Until his death in 1972, Robinson was also a big proponent of African American involvement in nonathletic positions (e.g., coaching, management, and ownership). For his steadfast example and praiseworthy skills, Jackie Robinson was inducted into the National Baseball Hall of Fame in 1962. Professional football and, last, professional basketball integrated their teams after World War II.

About the time of Jackie Robinson's rise to fame in baseball and baseball's integration, America was becoming integrated as well. Just as sports can reflect society, society can likewise mirror sports. With the integration of baseball, and other professional sports, came increased public awareness that integration was possible and could be successful. Integrated teams, such as the Brooklyn Dodgers, had record seasons and were winning the World Series. Two historical legal events that fostered societal integration were a Supreme Court decision and a congressional bill that became law. In the *Brown v. Board of Education* Supreme Court decision of 1954, the court ruled unanimously that applying the "separate but equal" clause in public schools was invalid and in opposition to the Constitution. The second event involved the passing of the Civil Rights Bill of 1964, which promotes equity and prohibits discrimination based on race, color, religion, or national origin with regard to activities conducted within a public area or establishment, as well as with regard to employment and pay.

Despite the Court's decision and this groundbreaking legislation, integration still had, and continues to have, its difficulties. Integration saw the end of many long-standing black establishments. With integration came the demise of the Negro Baseball Leagues, as all their great players were transferring to the national leagues, resulting in a smaller talent pool and loss of media coverage, fans, and sponsorship. A moving away from black culture also began at that time and continues to this day. Not all well-founded black entities were lost, however. The American Tennis Association, home of Arthur Ashe and Althea Gibson, still continues today, supporting the development of young African American tennis players within their communities. With their sound basis in African American communities, two other well-known black establishments survived integration: Motown and historically black colleges and universities.

Integration also saw the opening up of entities (e.g., educational, physical, socioeconomic, and medical) once closed to African Americans. Black athletes are now free to participate in any sport of their choice. Although their numbers are increasing, African American athletes still face discrimination in the type of sports in which they participate as well as in the positions they typically assume within those sports. They are more often seen in revenue-producing sports, such as football and track, than in more privileged sports, such as horseback riding and swimming. Eighty percent of college-going African American women athletes participate in two sports: basketball and track. Stereotyped as being natural, physical athletes, African American athletes are often funneled toward positions that require quickness and jumping, while white athletes are given positions that involve decision making, such as quarterback and pitcher. This mindset carries into the sports management arena as well. Black athletes more often find themselves in the dependent position of player than in the power position of owner or manager. Few blacks include themselves among the ranks of professional team owners, and none of those maintain controlling interests in those professional clubs. Black athletes, particularly the women, also may not receive the same amount of endorsements and public engagement opportunities. Although integration has taken place, the extent and quality of that integration is still in question.

Disability and Sport

Participation in sports benefits all individuals of all abilities. Participants develop an improved level of physical fitness as well as an improved mood state, experiencing less depression and anxiety. Disabled individuals should also benefit from sports participation; however, society has not always permitted their participation. When people attempt to assimilate disability and sports, they have three general reactions. The first is that the two cannot be brought together—"disabled," to some, implies an inability to perform many of the skills required in sports. Another reaction is that sports for the disabled should be a separate entity from the able-bodied sports arena. The last is an integrated view—that everyone should be able to participate, although some game modifications may be required.

Disabled Americans quietly face discrimination daily. For wheelchair-bound and other impaired individuals it could be difficult, if not impossible, to access public buildings, rooms, and other structures and activities. This lack of access served to sequester them from public view and public life. The sports world for disabled Americans was often limited to rehabilitative efforts. One notable exception was the development of the Special Olympics, with the aid of Eunice Kennedy Shriver and the Kennedy Foundation. The Special Olympics promotes the physical health and activity of the cognitively disabled.

The treatment of disabled Americans changed with the Americans with Disabilities Act of 1990, which prohibits discrimination by or in public services, activities, or entities because of a disability. Since that time, disabled Americans are experiencing greater access to public areas. For example, crossing the street can be conducted without difficulty, as sloping sidewalks help aid the transition to ground level. Gently sloping ramps provide access to public buildings that are otherwise inaccessible. Even fitness clubs have increased their accessibility to disabled individuals; however, equipment in the clubs may not always be accessible. In athletics, the law helped increase the participation of disabled children and adults in more mainstream activities, occasionally in modified sports, such as football and softball, two of the most commonly modified sports. Athletes with disabilities now receive athletic scholarships to school. Curricula for physical education teachers now include discussion and understanding of adaptive methods in athletics. The number of physical education and fitness classes for disabled individuals in colleges and universities has increased as well. Even equality of rehabilitation, which was the founding principle of physical activity for the disabled, has improved. The Americans with Disabilities Act also improved public awareness, perception, and understanding of disabilities and the issues facing disabled individuals. The act also fostered the standardization of various fitness facilities and equipment, such as the height of ski lifts, to benefit all individuals. The Paralympics, a division of the International Olympic Committee founded in 2001, has provided the world with a view of the elite, disabled athlete. Although inroads have been made, challenges in sport for the disabled still exist, in equality in access, education, funding, and representation.

Age and Sport

Although no landmark legislation exists to bolster it, participation in athletics for those at the more extremes of the age spectrum is steadily increasing. Children and senior citizens are both participating in sports more than in past years.

Children and Sport

Throughout the years, children's athletics has revolved around the arena of "free play," during which children may run around and play tag or take part in other, more unstructured games with few developed rules. Over the past 30 years, participation of children in organized sports has increased. Unfortunately, the amount of "free play" activities (e.g., recess, tag) has seen a concomitant decrease during the same time.

Sports participation by children has many benefits. Organized play allows for the development of rules that can augment the safety of athletes. Children participating in athletic games also have the opportunity to interact with their peers, in addition to improving their motor skills. As they learn to operate within the rules of the game, they also begin to learn game strategy. An additional benefit of child sports participation is that the participants will have a head start on being the adult athletes of tomorrow.

As with many activities with benefits, organized sports participation has some caveats as well. With the decrease in unstructured activities has come a decrease in routine physical activity in schools (e.g., physical education and recess) and in the home, leading to obesity and its associated health and psychosocial outcomes. The American Academy of Pediatrics, in a combined policy statement from the Committee on Sports Medicine and Fitness and the Committee on School Health, recommends the following with regard to organized school sports: Organized sports should complement unstructured play time (e.g., recess at school) so as to promote and continue a habit of leisure physical activity, and organized sports should be developmentally appropriate, to avoid too early participation in some sports and discouragement and athletic injury. One method of making sports more in line with children's development is alteration of the sporting event, by a change in the structure of the game, the field, the number of players on the field, the equipment used, or the total amount of time played.

Seniors and Sport

It is becoming increasingly evident that reaching old age does not necessarily mean a person has to act and feel old. The days of "weak" and "feeble" elders are quickly waning. In fact, research is demonstrating that continuing physical fitness and activity throughout one's lifetime can help prevent or ameliorate many of the symptoms of "aging," such as decreased aerobic power, decreased muscle mass and strength, decreased tissue elasticity, and decreased bone density. With or without this knowledge, older adults in the United States have demonstrated increasing participation in athletic activities, either as new participants or as those continuing their participation over the years. Sports leagues are growing in number for older athletes, including amateur, professional, and regularly scheduled national competitions, such as the Senior Olympics of the National Senior Games Association.

Conclusion

Diversity in sports and athletics provides the opportunity to involve the entire community, regardless of gender, race, disability, or age. This integrated community involvement can help promote tolerance as well as cultural sharing. With the past history of sport integration and the current level of sport diversity, the sports arena has come a long way but still has a long way to go.

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See also Gender and Age Differences in Response to Training; Mental Health Benefits of Sports and Exercise; Pediatric Obesity, Sports, and Exercise

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Doping and Performance Enhancement: A New Definition

A new definition of doping, in accordance with the World Anti-Doping Code of 2003, considers basically three facts: (1) the use of substances or methods able to artificially increment the performance of athletes, (2) that these substances will be harmful to the health of athletes, and (3) that it is against the spirit of the games.

Doping is contrary to the principles of the Olympics and sports medicine ethics. Doping is forbidden, as are recommending, proposing, authorizing, or facilitating the use of any substance or method included in this definition.

Types of Tests for Drugs

Urine and/or blood samples may be used for tests concerning drugs. Basically, according to the World Anti-Doping Code (WADA), there are two types of antidoping control to be done.

Controls In-Competition (IC)

The "in-competition" doping controls are done immediately after the end of a sports activity. In this type of control, the whole menu of substances and methods proposed by WADA in its "Forbidden List of Substances and Methods" is used.

Controls Out-of-Competition (OOC)

The "out-of-competition" controls could be done at any moment: during the training, in the house of the athlete, or even close to a competition.

The substances controlled in both kinds of tests are not the same. According to the Code, the out-of-competition tests include only anabolic agents, beta-2 agonists, agents with anti-estrogenic activity, diuretic and masking agents, and all banned methods. Stimulants, narcotics, and cannabis are not analyzed in this type of control.

List of Substances and Methods Banned by WADA

Every year, the prohibited list of WADA is revised by the List Committee and, after being ratified by the Health, Science and Medical Committee, it goes to the Executive Committee for approval. After that, the list is published on the Internet on October 1, and the prohibitions come into effect on January 1 of the coming year.

The list is used by all stakeholders, ensuring a real harmonization all over the sports world and the political world. The list opens with a sentence that mentions that "the use of any drug should be limited to medically justified indications" and begins by mentioning substances prohibited at all times.

To consult the current complete list with examples and explanations, please refer to the WADA site, http://www.wada-ama.org, under the head "Prohibited List."

Adverse analytical findings (AAFs) (for the year 2007) are that in non-Olympic sports, there is a 2.08% failure rate in doping tests, whereas in Olympic sports, that number is 1.93%. These numbers can be used to estimate the number of athletes using illegal substances. The total number of tests performed in non-Olympic sports (2.08) is greater than in Olympic sports (1.93), the average being 1.97%. This number can work well to estimate the number of athletes who use dope. The total number of doping control tests in the year 2007 was 293,898, which shows a clear increase in testing.

If we compare the findings of previous years, we find a percentage of increase from 1.62 in 2003 to 2.13 in 2005, but then a decrease to 1.96% in 2006. Perhaps this is a signal that the fight against doping is being won, particularly since education against doping is being emphasized for young people.

In 2007, WADA found that the most used doping substance was anabolic steroids (47.9%), followed by beta-2 agonists (16.4%), cannabinoids (11.9%), stimulants (8.2%), glucocorticosteroids (5.9%), and other substances (2.47%).

Among anabolic agents, the most prevalent substance to be found was testosterone (69.8%), followed by nandrolone (8.7%) and stanozolol (7.45%). Perhaps the athletes still believed that because testosterone is an endogenous hormone, the laboratories will find it difficult to detect.

Among stimulants, we see that amphetamines are still the most common (54%), followed by cocaine (13%) and ephedrine (6%). Cocaine is not used as a performance-enhancing drug because it is expensive, has a short action, and is easy to detect. It is mostly used as a social drug, although it is detected in the doping control.

The percentages of adverse findings among five sports were as follows: cycling, 3.91%; boxing, 3.16%; weight lifting, 3.02%; baseball, 2.69%; and basketball, 2.47%. Most of these are professional sports, and we can imagine projecting these findings onto the four big professional leagues in the United States, even if American football is not an Olympic sport.

As mentioned before, and must be always stressed, the AAF expressed in these results is *not* equal to an antidoping rule violation (ADRV). We must first exclude all the Therapeutic Use Exemptions (TUE) and provide the possibility of a fair and timely hearing for the athlete. But, no doubt, the AAFs are a very useful indicator.

Doping Control in Blood: A New Technology

Drawing blood samples to detect some doping substances or doping methods began in the Olympic Games of Sydney in 2000, and this method was very much in use in the Athens (2004) and Beijing (2008) Olympics.

It is possible to increase oxygen transportation and delivery to the tissues in the blood. In the first case, this includes blood transfusions, the use of hemoglobin substitutes, and an increase of red cells with erythropoietin (EPO). Blood transfusion is classified as autologous (the blood donor is the same person) and allogeneic (the blood donor is a different person). The technique of flow cytometry successfully identified mixed antigenic populations in patients who were transfused with at least 1 unit of homologous blood.

The most common use of hemoglobin substitutes in doping is the hemoglobin-based oxygen carriers (HBOCs). Genetically modified NESP (novel erythropoiesis–stimulating protein or darbepoietin alpha, another synthetic form of EPO) is strong and long-lasting. A blood test developed by scientists at the Australian Institute of Sport has been used during the last two Olympic Games and was instrumental in detecting the use of NESP by several cross-country skiers in Salt Lake City.

There is also the possibility of using the "natural" way to produce EPO by decreasing the tension of oxygen, which tends to simulate altitude and helps in altitude training. Direct and indirect methods can be applied to detect exogenous EPO. To increase oxygen delivery to the tissues, athletes are using allosteric modulators, natural or synthetic, such as Efaproxiral (RSR 13). Artificial substitutes for red blood cells may also be used as doping. They provide immediate oxygen delivery, and the compatibility is universal. The shelf life is much greater than for red cells. The raw material is bovine hemoglobin, and it is processed to remove infectious agents.

The correct technique of blood sampling is as follows: After notifying the athlete, have him or her relax for 10 minutes before undergoing a venous puncture by a phlebotomist. During this time, the digitally controlled oscillator (DCO) should provide an explanation of the sampling procedure. After selecting the kit and verifying its integrity, the numbers are verified and the labels placed on the tubes. The phlebotomist asks for the nondominant arm, places the tourniquet, and cleans the skin. After inserting the needle, the tourniquet is removed, as is the blood sample.

If the blood screen is for hematological parameters, only one sample of 3 milliliters (ml) of whole blood is analyzed. Therefore, the tube used should contain an anticoagulant. The contents should be gently mixed and sent to the laboratory.

For analysis of whole blood for evidence of prohibited substances and methods, such as blood transfusions, two blood samples are collected. The volume should be 3 ml per sample. The tubes again contain an anticoagulant. The contents should be gently mixed two or three times and sent to a laboratory. For analysis of serum for prohibited substances, two samples should be taken in tubes that have a silicon serum separator gel and a clotting activation factor. The tubes should be inverted gently five times to accelerate clotting. The samples should then be placed in the two specially adapted containers; the athlete finally seals them and completes the paperwork. In the Winter Olympics of Turin, a special Berlinger kit was designed by the Chief of Doping Control, and the waiting time for the athlete was much reduced in the process, because the blood sample was hermetically sealed before centrifugation.

Gene Doping: The Future Technology

The future of doping is considered by WADA to be gene doping. It has already been mentioned in the list of banned substances since 2000, and gene manipulation is defined by the agency as "the non-therapeutic use of cells, genes, genetic elements, or modulation of the gene expression, having the capacity to enhance athletic performance."

Since the mapping of the human genome, it is evident that it could be used, as common medications are, to try to increase the athlete's performance. The agency concerns were expressed by its chairman in a recent publication: "Gene doping may represent a new frontier in athletic performance enhancement, but we are working hard to ensure that these emerging medical techniques are not used to create super athletes."

Genetic potential was considered as one of the most important factors of performance in athletes, and until now this potential could not be altered. It is possible that genetic screening at an early age—that is, comparing the human genome and better conditions of genetic potential in each sport—will be used to select and train better athletes according to their abilities.

The use of viral factors to deliver a gene to the athlete is the most effective and also the most expensive method to be used, although compared with nonviral factors, viral factors have a higher toxicity and can produce an immune reaction that may sometimes cause rejection. The nonviral factors are effective only locally, and in consequence, they have fewer general effects. They are easy to prepare and have less risk of contamination.

Today, gene doping may be a reality in athletes. The production of the red cell through genetically modified erythropoietin, which may not be detectable by a urine test; muscle hypertrophy in healthy subjects using myostatin; and the production of new vessels that should be useful to increase oxygen transfer in the tissues of athletes are all possibilities.

It is possible to find in the literature three studies that clearly show this tendency. The Belgian Blue is a type of cattle known to have a bigger muscle mass than conventional cattle. On examining the expression pattern and sequence of the gene in normal and double-muscled cattle, a mutation within the myostatin gene was found. *Myostatin* is a negative regulator of muscle growth in cattle as well as mice.

Viral expression of insulin-like growth factor 1 (IGF-I) without resistance training produced a 14.8% increase in mass. Combined with training, this produced a 31.8% increase in muscle mass in mice. These results suggest that a combination of resistance training and overexpression of IGF-I could be an effective measure for attenuating the loss of training-induced adaptations.

Scientist from South Korea and the United States developed a Marathon Mouse, an engineered mouse that ran 1,800 meters (m) before quitting and stayed on the treadmill longer than the normal mice, which could run only 900 m. The genetically engineered animal has been given an enhanced protein that turns it into an "endurance athlete" and makes it resistant to weight gain.

Today, gene doping is still a question mark. Can it be stopped, or will the cells multiply, causing diseases and later death? Will the immunological risk be uncontrolled, and will it complicate the response of the body? Will cell mutations be transferred to the following generations? The medical, ethical, and legal implications will be evaluated by physicians and scientists dealing with such techniques.

The Science and Medical Committee of the WADA established a Gene Doping Panel in 2005, chaired by Professor Theodore Friedman, a pediatrician who is the director of the gene therapy program at the University of San Diego. He believes that this technology is evolving very rapidly, considering that the science involved is not very difficult and can be carried out by well-trained people in thousands of laboratories all over the world. Many scientists believed that already in the Beijing Olympics some degree of gene doping was possible.

Will it be possible to detect gene doping? In the opinion of many scientists, the answer is yes. If we revisit the story of doping, this same question was asked many times, and the answer was always yes. Anabolic steroids have been detected, including testosterone. Masking agencies and hormones have also been detected, as well as synthetic steroids.

The UNESCO Convention Against Doping in Sport

It is important to understand that WADA is a private entity that brings together the Olympic Movement and the governments of participating countries. Were WADA to have its legislation approved by the governments or to collect the proper fees from them, it would be a problem, because the countries will not accept norms or transfer funds to such an entity. To solve this problem, the General Conference of UNESCO approved a Convention Against Doping in Sport, which was subscribed by 30 members in December 2006. More than 196 countries have already ratified the convention, and this number is growing steadily. It defines the Accredited Doping Laboratories, the Anti-Doping Organizations, antidoping rules violation, and the terms *athlete, code, competition,* and *doping control,* as well as the criteria of *no advance notice, out-of-competition, in-competition, prohibited list,* and *therapeutic use exemption.*

During the first Conference of Parties to the International Convention Against Doping in Sport, a chairperson, four vice-chairs, and a speaker's position were established, and the Rules of Procedure were adopted. Other key items for discussion included administration of the Fund for the Elimination of Doping in Sport, building antidoping capacity around the world, and consideration of a monitoring framework in support of the convention. The Conference of Parties also adopted the 2009 Prohibited List.

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See also Doping and Performance Enhancement: Historical Overview; Doping and Performance Enhancement: Olympic Games From 2004 to 2008; Performance Enhancement, Doping, Therapeutic Use Exemptions; World Anti-Doping Agency

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Doping and Performance Enhancement: Historical Overview

The use of doping—that is, using drugs for performance enhancement in sports and otherwise—has a long history. The first document related to the use of doping agents was a painting of the Chinese emperor Shen-nung, in 2737 BCE, showing him using ephedrine in his tea. This emperor is considered to be the father of Chinese medicine and is believed to have introduced the art of acupuncture. He also classified the medicinal herbs according to their pharmacological effects.

In the ancient Olympic Games, at the end of the 3rd century BCE, the athletes believed that drinking herbal teas and eating mushroom could increase their performance during the competitions. In South America, stimulants—ranging from the virtually harmless maté tea and coffee to strychnine and cocaine—were used to increase performance. Spanish writers report the Inca Indian runners chewing coca leaves to help them cover the distance between Cuzco and Quito, in Ecuador.

In 1886, 10 years before the inauguration of the modern Olympic Games, the first fatality caused by doping was reported, when a cyclist named Linton died after an overdose of a stimulant in a race between Bordeaux and Paris.

Origin of the Word *Doping*

The origin of the term *doping* is controversial, but it seems to have come from a South African dialect. For the Boers, it means an infusion used in religious festivities—the "doop." And according to Burstin, during the construction of the North Channel in Amsterdam, workers used the term *doopen* when referring to increasing their capacity to work. In 1889, the term *doping* appeared in an English dictionary, meaning "a drug used to stimulate horses." From the horses in the hippodrome, the term soon began to be applied to people in the stadiums. The modern definition of *doping,* as used by the World Anti-Doping Agency (WADA) in 2000, is any substance or method that (a) is used to increase the performance of an athlete, (b) is harmful to the health of the athlete, or (c) is against the values of the game. When two of these three conditions are present, a substance or a method may be banned by inclusion in the "List of Forbidden Substances" of the WADA.

Doping in the First Olympic Games (1886–1932)

The modern Olympic Games were inaugurated by Baron Pierre de Coubertin in Athens in the year 1896. The philosophy of the Baron was that competing in the games was more important than winning them, and as a consequence of that, the incidence of doping was very low, restricted to some contamination in cycling and track-and-field events. The substances used to increase performance were cocaine, ephedrine, and strychnine, mixed together in a small pellet.

In 1928, during the Winter Games in St. Moritz, Switzerland, sports physicians from many countries decided to create the International Federation of Sports Medicine (FIMS) to protect the health of Olympic athletes and provide a forum to discuss their problems. The first international sports federation to ban the use of doping agents in sports was the International Association of Athletic Federations (IAAF), in 1928. Until 1932, the Olympic Games were held regularly, excluding the years of World War I.

In Germany, Hausschild developed pervitin in 1934, and in England, methedrine was synthesized—both being used for night flights, long marches, and other endurance events during World War II. Amphetamines were produced for the first time in 1938 and were also used as a strong stimulant during the period of the war.

The Olympic Games From 1936 to 1960

From 1936 to 1960, the Olympic Games were held regularly, excluding only the period of World War II. In 1936, the Berlin Olympic Games were used by Germany as a political instrument to promote the Aryan race. Thus, the ideals of Coubertin were shattered, as winning the games became much more important than simply competing in them. The substances most used after World War II were amphetamines and anabolic steroids, synthesized substances similar to the male hormone testosterone. Anabolic steroids were first used after World War II, when U.S. Army physicians were faced with the rehabilitation of the prisoners from Germany's concentration camps. Those physicians discovered that the male hormone was the only substance that could increase muscle mass.

In 1954, athletes started to use anabolic steroids to increase muscle mass and consequently to achieve more power. First introduced to weight lifting and bodybuilding athletes, this substance reached all track-and-field events and then other sports. In 1960, at the Olympic Games in Rome, a cyclist from Scandinavia died in the road competition after an overdose of a stimulant. The name of the athlete was Jensen, and he had used isopropylamine and amphetamine, ingested with coffee.

Because of bad press for the Olympic movement, Lord Porrit was appointed to create a Medical Commission in the Executive Committee of the International Olympic Committee (IOC). In the Tokyo Olympic Games, testing for drugs was done on cyclists during some competitions, but due to many difficulties, it could not be totally implemented. After that, Dr. Albert Dirix wrote a letter to Avery Brundage, president of the IOC, demanding strong action against doping in sport.

At the Congress of Moscow, in 1962, the IOC passed a resolution against doping. Lord Porrit became an honorary member, and the young Prince Alexander de Merode of Belgium was appointed to chair the Medical Commission and to fight against the use of doping agents in sports. The members of the Medical Commission held their first meeting in Lausanne, Switzerland, on September 27, 1967.

Doping controls directed by the IOC Medical Commission were in place for the Winter Olympic Games at Grenoble, France, and for the Summer Olympic Games at Mexico City in 1968.

The Olympic Games From 1968 to 1980

The IOC's first list of banned pharmacological classes was published in 1968, and it included the following substances:

- Psychomotor stimulant drugs
- Sympathomimetic amines
- Miscellaneous central nervous system stimulants
- Narcotic analgesics

Italy and Uruguay adopted antidoping legislation in 1971, and in the next year, anabolic steroids were added to this list just before the Montreal Olympic Games.

For the Montreal Olympic Games in 1976, the same list was maintained, and two beta-2 agonists were permitted: salbutamol and terbutaline. There was a caveat: The IOC Medical Commission was to be informed prior to their use, which was the origin of the Therapeutic Use Exemption (TUE). During this period, doping was found in all Olympic Games, except the Moscow Games in 1980. Many observers believe that in fact doping was a part of those games, but that because of the political climate at the time, the test results were not clinically analyzed.

The control of anabolic steroids in Montreal in 1976 is considered an important cornerstone of the fight against doping, because this substance had been widely used by athletes for more than 20 years.

The Olympic Games From 1984 to 2000

At the Olympic Games in Los Angeles, there were 11 positive cases, a high number. False medical certificates of hypertension were used in Los Angeles to justify the use of beta blockers. Diuretics were very much in evidence in sports where the category of the athlete is dictated by weight. Blood transfusions were used in cycling, and physical manipulation of urine was done in weight lifting. Once again, the IOC Medical Commission modified the list of banned pharmacological classes in 1987, now including beta blockers and diuretics. Restricted substances and forbidden methods of administration were also included in this list, to prevent the use of local anesthetics and corticosteroids, as well as blood transfusions and the physical manipulation of urine.

Probenecid was also detected in the Pan American Games of Caracas a year before the Los Angeles games, and it was included in the list as a pharmacological manipulation of urine. A system of escorts was also created by the IOC Medical Commission to accompany the athletes after their notification, in order to avoid physical manipulation of urine in the dressing rooms.

In the 1968 Summer Olympics Games at Seoul, it was believed that the athletes had learned their lesson and that only a few positive controls would be detected. Unfortunately, many cases were detected. After those games and after the discovery of erythropoietin (EPO) and human growth hormones (HGH) at the Winter Games of Calgary, the IOC Medical Commission banned peptide hormones. Anabolic steroids were changed to androgenic anabolic steroids, including beta-2 agonists. Since the use of anabolic steroids was often stopped 15 days before the games to avoid detection, out-of-competition doping control started after the Olympic Games in many international sports federations. This was also conducted by the IOC.

Doping at the Olympic Games in Barcelona, Spain, was not a major issue, and only five cases were detected, two of them after the use of clembuterol. The other cases were caused by strychnine, norephedrine, and mesocarb use. After those Games, there was a new change in the list of banned pharmacological classes and methods. The concept of "related substances" was changed to include not only the chemical structure but also pharmacological action. For this reason, a new class of anabolic agents was established, including the anabolic androgenic steroids and also the beta-2-agonists.

The pharmacological class of beta blockers was removed from the banned area and placed on the restricted list, but it was still banned in some sports, such as shooting, archery, pentathlon, equestrian, diving, and sailing. The most important decision after these games was to include the possibility of blood sampling of athletes, in conjunction with urine sampling, to permit better determination of blood transfusion and the use of hormones.

At the 100th anniversary of the Olympic Games, in Atlanta in 1996, there were two athletes detected using anabolic steroids. However, 10 athletes from Russia and Bulgaria tested positive because of Bromantan, a new stimulant amphetamine type of drug produced by the Russian army. These athletes, penalized by the IOC Medical Commission, were later on reinstated by the Tribunal Arbitral of Sports (TAS) because Bromantan was not on the list of banned substances. After Atlanta, Bromantan was added to the list before the next Winter Games.

For the Sydney Olympic Games, the banned list included three peptide hormones and one prohibited method, and the term *marijuana* was changed to *cannabis*. Blood samples were collected for those participating in aerobic sports, and these and urine samples were both collected after the opening of the Olympic Village but before the beginning of the competitions (see Table 1).

The Founding of WADA

In 1968, after the Tour de France, which had concomitant problems around doping, the International Olympic Committee called for an international congress, the result of which was the creation of

Table 1 Doping Tests Performed in the Olympic Games, 1978–2008

Games	*City*	*Number of Tests*	*Stimulants*	*Anabolic Steroids*	*Others*
1972	Munich	2,079	7		
1976	Montreal	1,896	3	8	
1978	Mexico	667	1		
1980	Moscow	1,645	0	0	
1984	Los Angeles	1,887	1	11	
1988	Seoul	1,998	2	3	4
1992	Barcelona	1,842	3	2	2
1996	Atlanta	1,795	0	2	0
2000	Sydney	2,052	1	3	4
2004	Athens	2,800	2	7	5
2008	Beijing	4,770	0	14 (total)	7

Source: Eduardo Henrique De Rose; based on IOC data.

the World Anti-Doping Agency, or WADA. In 2003, the world antidoping code was established, with a complete list of banned substances and methods. Today, this agency works in the areas of medical science, education, and ethics. The Independent Observer Programs audit doping controls in world and regional competitions, and the Outreach Program is directed at athletes in major competitions.

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See also Doping and Performance Enhancement: Olympic Games From 2004 to 2008; World Anti-Doping Agency

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Doping and Performance Enhancement: Olympic Games From 2004 to 2008

Doping and performance enhancement are much more severely regulated than ever before following the 2000 Olympics. The World Anti-Doping Agency (WADA) was established, and the International Olympic Committee (OIC) established a Disciplinary Committee to rule on the elimination of athletes who were found to have banned substances in their systems in the Winter Games at Salt Lake City, and at the Olympiad in Athens, a month-long "Olympic period" was established wherein doping controls were conducted on all athletes participating in the games inside and outside Greece. Out of 2,800 controls performed, 11 positives were discovered, predominantly in weight lifting.

After the games were completed, there were 14 positives. Three of these were refusals by the athletes to participate in the tests, one of them even a gold medalist! For the first time in history, human growth hormones were found in the blood of 380 athletes. All cases were judged by a Disciplinary Commission formed by three IOC members, with the final approval of the Executive Committee. The Medical Commission randomly supervised doping control and the medical care of the athletes.

The same system was maintained for the Turin Winter Games, in 2006. The IOC established an Olympic period, from the opening to the closing of all Olympic Villages. During this time, 616 urine samples and about 300 blood samples were collected from the athletes. Only one female athlete, from Belarus, from the biathlon team, had an adverse analytical finding (AAF) for stimulants. The laboratory in Turin worked under a temporary accreditation by WADA, assisted by 11 directors of accredited laboratories in the Games.

The Beijing Games were one of the best-organized Olympic Games, and the doping control was excellent. President Jacques Rogge called for an Olympic Games with zero tolerance in the area of doping, and a record number of tests were conducted, both before and during the competition. In the period from the opening of the Olympic Village until 2 days after the closing ceremony, the IOC performed 4,770 urine and blood tests. At this time, 15 violations were detected, including six horses being given forbidden substances.

After the Tour de France in the same year, the Laboratory of Doping Control in France was able to detect a new type of erythropoietin (EPO), a continuous erythropoiesis receptor activator (CERA). Because of that, the IOC asked for a review of the urine samples of Beijing athletes collected after January 1, 2009, in Lausanne. These results were publicized at the end of May 2009, and six other athletes were punished.

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See also Doping and Performance Enhancement: Historical Overview; World Anti-Doping Agency

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Dual-Energy X-Ray Absorptiometry (DEXA)

Dual-energy X-ray absorptiometry (DEXA) is an advanced form of X-ray technology used to assess the strength of the bones and their weight-bearing capacity by measuring the density of various minerals (such as calcium) in the bone. It is the most routinely done bone mineral density (BMD) test and is the most accurate in detecting loss in bone mass (osteoporosis).

Peripheral dual-energy X-ray absorptiometry (p-DEXA) is a type of DEXA test. It measures the density of bones in the arms or legs, such as the heel (calcaneus), shinbone (distal tibia), or kneecap (patella).

Relevance in Sports Medicine

In sports, a decrease in the bone density means increased risk of fractures due to the reduced ability of bones to bear stress as well as the frequent occurrence of trauma during athletic contests. DEXA scans can play a pivotal role in the early detection of osteoporosis, especially in women athletes, who are at higher risk. Determining a person's BMD can help detect if a person is at increased risk for an osteoporosis-related fracture. It can also be used to decide whether prescription medicine therapy is needed to help reduce the risk of such a fracture. It may help in deciding whether the bone loss is significant enough to reduce the workout plan for such athletes. Additionally, if a patient has a fracture or is planning to have orthopedic surgery, a diagnosis of osteoporosis might affect the surgical plan.

Mechanism

A DEXA scanner produces two low-dose X-ray beams, each with distinct energy peaks. These are passed through the lower spine and the hip as these are the most common regions to be fractured owing to osteoporosis. The soft tissues absorb one of the peaks, whereas the bone absorbs the other. The amount of X-rays of each beam that pass through the bone are sensed by a detector. Subtracting the soft tissue absorption and comparing the amount of the two beams records the BMD. The result depends on the thickness of the bone, since weak bones allow more of the X-rays to pass through them than do normal bones.

Procedure

During the central DEXA examination, the patient lies on a table with an X-ray generator below him, and an imaging device, or detector, is positioned above. The spine is assessed by supporting the patients' legs on a padded box to flatten the pelvis and lower (lumbar) spine. For the hip, the patient's foot is placed in a brace so that the hip is rotated inward. The detector passes over the regions and records the images. The procedure may take 15 to 20 minutes.

The p-DEXA machines are portable units and give results in a few minutes. During peripheral tests, the finger, hand, forearm, or foot is placed in a small device, and the bone density is recorded.

Lateral vertebral assessment (LVA) is a low-dose X-ray examination of the spine that is performed on the DEXA machine. It is an additional test to screen for vertebral fractures.

Analyzing Results

A DEXA scan result can be scored in two ways:

1. T *score:* This number compares the bone density with that of a young adult of the same gender having an optimal peak bone density. It is recorded as numbers of standard deviations below the average. It estimates the gradual bone loss and the increased risk of developing fractures.

   - *T* score of greater than –1: normal
   - *T* score of –1 to –2.5: osteopenia (low bone mass) and a risk for developing osteoporosis
   - *T* score of less than –2.5: osteoporosis (diagnostic)

2. Z *score:* This number compares results for people of the same age, size, weight, ethnicity, and gender. It assesses whether there are factors other than the normal wear and tear that are contributing to the bone loss. A *Z* score of less than –1.5 indicates factors such as thyroid abnormalities, malnutrition, medication interactions, alcoholism, and tobacco use. Further tests may be required.

Conditions Suggesting a DEXA Scan

All factors that predispose a person to the risk of bone loss suggest a DEXA scan. According to The National Osteoporosis Foundation's guidelines, women over 65, younger postmenopausal women having osteoporosis risk factors, as well as those with specific fractures should undergo a scan. Men who are affected due to advancing age or having any clinical condition causing bone loss should also proceed with a scan.

Other major conditions include the following:

- A fracture following a minor fall or injury
- A hip fracture in adult life or in maternal history

- Low body weight or thin stature
- A thyroid or parathyroid condition, such as hyperthyroidism or hyperparathyroidism
- A medication that causes bone loss, such as corticosteroids, various antiseizure drugs, certain barbiturates, high-dose thyroid replacement drugs, or oral contraceptives
- Type 1 diabetes, liver disease, kidney disease, or a family history of osteoporosis
- X-ray evidence of vertebral fracture or other signs of osteoporosis
- Early menopause (at age less than 45 years) or a history of amenorrhea for more than 1 year before menopause
- Other related disorders, such as rheumatoid arthritis or celiac disease
- Poor health, lifelong low calcium intake, or low physical activity
- Cigarette smoking, excessive alcohol intake, or caffeine consumption

Precautions

The following precautions must be taken before a DEXA scan:

- DEXA scans are not advised in pregnancy to prevent exposure of the fetus to radiation.
- Calcium supplements should be stopped for at least 24 hours before the test.
- A gap of 10 to 14 days is mandatory if another similar procedure, including X-rays with contrast media (e.g., barium enema, thyroid tests), has been performed.

Advantages of DEXA

DEXA has several advantages:

- DEXA scans are much more accurate than standard X-rays because X-rays show changes in bone density only after 20% to 40% of bone loss, whereas a DEXA scan can detect even a 1% change.
- Because they are low dose, less radiation exposure occurs (about 0.01 millisieverts [mSv]) with DEXA scans than with computed axial tomography (CAT) scans or X-rays.
- DEXA is less costly than other tests.

Current Medical Uses

DEXA can serve a variety of purposes:

- DEXA is the technique most often used to diagnose osteoporosis accurately.
- It is effective in estimating the effects of treatment for osteoporosis and other conditions that cause bone loss.
- The DEXA test can also assess an individual's risk for developing fractures.
- In children, DEXA scans are being used to determine bone development and the efficacy of treatment in conditions such as nutritional rickets, Turner syndrome, and so on.
- It may be used by pediatricians in diagnosing and monitoring the treatment of disorders of bone mass acquisition.

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See also Osteoporosis Prevention Through Exercise

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Dysmenorrhea

Dysmenorrhea is a syndrome that encompasses a cluster of unpleasant symptoms experienced during the onset of a woman's menstrual cycle. The defining symptom is lower abdominal and pelvic cramping. Many other symptoms can occur as well (see list below). Symptoms begin during the hours surrounding the start of menstrual flow and continue for 24 to 48 hours. Roughly 75% of adolescent women experience some degree of dysmenorrhea, making it the most common gynecologic complaint in this age-group.

The diagnosis can be further categorized into primary dysmenorrhea and secondary dysmenorrhea. In the primary form, no specific medical abnormality can explain the symptoms. Primary dysmenorrhea represents 90% of cases, is associated with a normal menstrual cycle, and is not associated with pelvic pathology. Symptoms usually begin 6 to 12 months after menarche, when menstrual cycles become regular and ovulatory. Secondary dysmenorrhea commonly appears 1 to 2 months after menarche or after age 25. Causes of secondary dysmenorrhea include endometriosis, anatomic reproductive tract abnormalities, surgical adhesions, pelvic inflammatory disease, uterine fibroids, or ovarian cysts.

Symptoms of Dysmenorrhea

- Pelvic and abdominal cramps
- Diarrhea
- Nausea
- Tachycardia
- Vomiting
- Facial blemishes
- Loss of appetite
- Flushing
- Headaches
- Sleeplessness
- Backaches
- Depression
- Leg aches
- Irritability
- Sweating
- Nervousness
- Weakness
- Dizziness

Dysmenorrhea and Exercise

Anecdotal claims assert that physical activity alleviates symptoms of dysmenorrhea. Lay magazines and websites often include these statements. A comprehensive review of the literature in 2008 showed no well-designed studies to prove these claims. Many studies cited had methodological flaws and contradictory results. Yet the belief remains popular. As exercise does not adversely affect symptoms or menstrual irregularities and exercise has numerous other physical and emotional benefits, patients should be encouraged to maintain their routine as tolerated. The dysmenorrheic athlete should be evaluated and treated similarly as a sedentary individual.

Etiology of Primary Dysmenorrhea

The physiologic etiology is generally attributed to the effects of prostaglandins, specifically $PG_{F2\alpha}$ and PG_E. These compounds are released during the second half of a woman's menstrual cycle as a result of falling hormone levels. They are linked to uterine contractions, decreased uterine blood flow, and increased sensitization of pain fibers. As the prostaglandins distribute through the systemic blood stream, they also affect other organ systems. Medical inhibition of prostaglandin synthesis leads to reduction of symptoms.

Behavioral factors can also influence the disease course. Stress can lead to worsening of symptoms. Cultural taboos surrounding the menstrual cycle can influence associated behaviors. Benefits of secondary gain (e.g., time off work) can also be considered. The incidence of dysmenorrhea increases significantly among relatives. Whether this is related to a genetic predisposition or learned behavior is not known.

Clinical Evaluation

A thorough history and physical examination are essential during the initial evaluation. The medical history should include age at menarche, menstrual cycle length and regularity, sexual and obstetric history, risk factors for sexually transmitted infections, and whether the patient had previously undergone abdominal or pelvic surgery. Additionally, family history and evidence of increased psychological stress are important keys to the underlying etiology.

The physical exam should include a brief evaluation of major organ systems and should focus on the abdomen and pelvis. By definition, the examination of a patient with primary dysmenorrhea will be normal. During the pelvic exam, attention should be paid to signs of secondary etiologies. A scarred external cervical os may indicate cervical stenosis. Inflammation and purulent discharge suggest infection, and appropriate cultures should be taken. Occasionally, the clinician may see tissue consistent with endometriosis in the vagina or on the cervix, which implies more extensive pelvic involvement. A bimanual exam may reveal reproductive tract abnormalities or abnormal pelvic masses.

Diagnostic Tests

Most cases of dysmenorrhea can be diagnosed and managed with a thorough history and physical examination. However, if abnormalities reveal themselves, additional testing may be necessary. Also, if a patient with presumed primary dysmenorrhea does not respond to medical management, she may benefit from further testing. Pelvic imaging with ultrasound is the initial step. Based on the results, referral to a specialist in gynecology may be indicated.

Treatment

Primary dysmenorrhea is easily managed in an outpatient clinic. Social, physiologic, and predisposing factors need to be addressed. Treatment of secondary dysmenorrhea depends on the underlying etiology and is beyond the scope of this entry.

Behavior modification can be explored if the initial history and physical exam suggest social triggers. Methods to decrease stress, including meditation and yoga, may be beneficial, particularly around the onset of menses. A conscious effort to decrease work and family-related demands during this time can also reduce the symptoms.

Nonsteroidal anti-inflammatory drugs (NSAIDs) are the usual first-line treatment. These medications inhibit prostaglandin synthesis, thereby decreasing pelvic and systemic symptoms. Clinical testing has not proven the superior efficacy of any one type or brand of NSAID. Ideal dosing begins 1 to 2 days prior to the onset of menses and continues for 3 to 4 days. Adequate pharmacological dosing is crucial; subtherapeutic dosing is often ineffective.

Patients whose symptoms respond only partially to NSAIDs can consider pharmacological contraceptive options for further relief. These medications act by decreasing endometrial growth over the course of the menstrual cycle. Less endometrial growth limits the production of prostaglandins. Options include oral, vaginal, or transcutaneous combination contraceptives or intramuscular, subdermal, or intrauterine progesterone contraceptives. Selection should be tailored to each patient, with close attention paid to the side effects of each type.

Nonpharmacological treatment can be very effective, and patients often successfully treat themselves with these modalities. Vitamin E inhibits prostaglandin synthesis by a different mechanism from that of NSAIDs and has shown positive effects. Dosage is 200 international units (IU) twice daily. Omega-3 fatty acids also aid in decreasing symptoms by decreasing the potency of uterine prostaglandins. Heating pads placed about the pelvis during symptom flares can also significantly decrease pain.

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See also Amenorrhea in Athletes; Female Athlete Triad; Menstrual Irregularities

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E

Ear Infection, Outer (Otitis Externa)

Otitis externa, also known as "swimmer's ear," is defined as an inflammation of the external ear canal. It is the most common medical (nonorthopedic) problem seen in athletes involved in aquatic sports. Otitis externa can be classified into five different types: acute diffuse, localized, chronic, eczematous, and malignant or necrotizing. By far, the most common is acute diffuse, on which this entry focuses.

Anatomy

For purposes of study, the ear is divided into three parts: (1) the outer or external ear, (2) the middle ear, and (3) the inner ear. The inner ear contains the organs of hearing (cochlea) and balance (vestibule and semicircular canals). The middle ear is the space between the tympanic membrane (eardrum) and cochlea and contains the three ear bones, or ossicles, that transmit sound vibrations from the tympanic membrane to the cochlea. The outer or external ear includes the pinna or auricle, the visible part of the ear; the auditory or external ear canal; and the outer surface of the tympanic membrane. The functions of the external ear are to direct sound to the tympanic membrane and to protect the middle and inner ears from injury. The external ear canal averages 2.5 cm in length and is lined with skin. The skin of the outer third overlies cartilage and contains hair follicles and glands that produce oil and cerumen (ear wax). The inner two thirds of the canal have bony walls with a thin, tightly adhered layer of skin with no hair or glands (Figure 1).

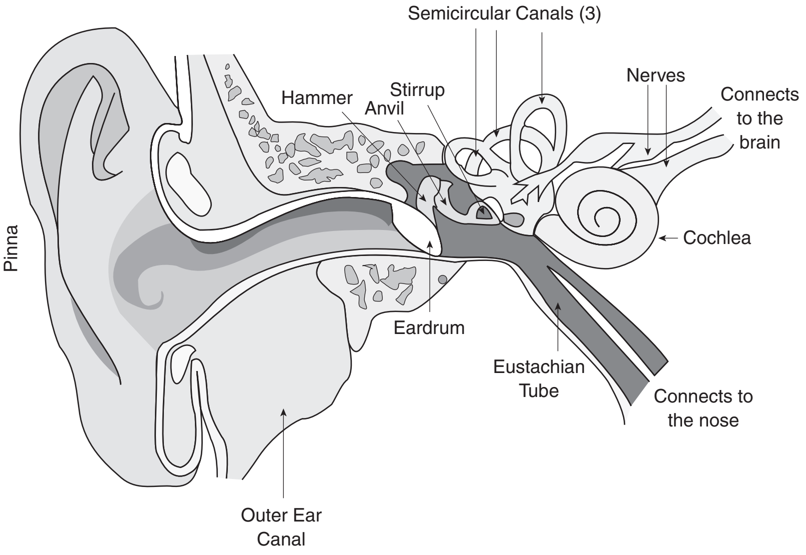

Figure 1 Anatomy of the Ear

Epidemiology

As mentioned above, acute otitis externa (AOE) is one of the most common medical problems seen in aquatic athletes, but it does not affect only athletes. The annual incidence is between 1 in 100 and 250, and 10% of all people will have a case of AOE in their lifetime. Approximately 7.5 million prescriptions are written annually in the United States for treatment of AOE. People living in warmer climates and those who have more water exposure are more likely to be affected.

Swimming in polluted or inadequately chlorinated water also increases the risk. A history of allergic rhinitis, asthma, or eczema increases the risk by three times.

Causes

AOE is believed to be caused by a number of different factors. *Cerumen* (ear wax) is thought to be important in maintaining a healthy environment in the external ear canal. Being slightly acidic, it helps inhibit infection. Its lipid nature also helps protect the skin of the canal from damage due to excess moisture. People who produce inadequate cerumen, thus, have an increased risk of AOE. If cerumen is removed by regular cleaning or excessive water exposure, then that important barrier is eliminated. This may cause the ear canal to itch. If the skin of the ear canal is then injured by attempts to scratch the canal with a cotton swab or other device, it provides a portal for bacteria to infect the skin. Other ways in which the lining of the canal can be injured include tools used to remove excess cerumen, irrigation, or hearing aids.

Another mechanism for infection is when there is too much cerumen production or if there is an underlying skin disease that causes increased sloughing of skin cells. The excessive debris can then trap water in the canal, resulting in skin maceration and creating an excellent culture medium for bacteria. A third means by which AOE can occur is as a result of purulent secretions from an acute otitis media (middle ear infection) in patients with a ruptured tympanic membrane or tympanostomy tubes.

While most cultures of patients with AOE show that the infection is caused by many bacteria simultaneously, the most commonly isolated bacteria are *Pseudomonas aeruginosa* (20%–60%) and *Staphylococcus aureus* (10%–70%). These organisms are present in most swimming pools, hot tubs, and natural bodies of water. Some studies have shown a correlation between water quality and risk of AOE, but even water that has been properly treated will still have these pathogens.

Symptoms

The first presenting symptom of AOE is often itching (pruritus). Then over the next 24 to 48 hours, the itching will progress to a gradually increasing otalgia (ear pain). This pain is often intense and may be disproportionate to findings on exam. Patients will also sometimes complain of pain worsened by chewing. Patients also often have a feeling of fullness in the ear, and some may develop drainage (otorrhea). The drainage is usually thin and clear to white, but it may become thicker and yellow or green without treatment. If the swelling or drainage is severe enough, the patient may develop hearing loss in the affected ear.

Diagnosis

Physical examination can usually help make the diagnosis of AOE straightforward. The classic finding is tenderness with pressure on the tragus (the small cartilaginous projection anterior to the external canal) and/or pulling on the pinna. Visualization of the external canal with an otoscope generally shows diffuse ear canal redness and swelling. Evidence of debris is also often seen. AOE can mimic otitis media (middle ear infection) as it can cause redness of the tympanic membrane, but pneumatic otoscopy or tympanometry will show normal tympanic membrane mobility in AOE, while mobility will be limited or absent in otitis media. Lymph node enlargement is often noted in the periauricular and cervical nodes. Fever is rare, but when it is present, it is generally low grade. If the temperature is >38.3 °C (101 °F), then other diagnoses should be considered.

Treatment

Treatment of AOE usually involves three facets: clearing of debris, topical medications, and pain control. For medications to be delivered to the infected tissue, it is essential to clear any excess debris from the external ear canal. Most authors recommend gentle lavage with body temperature water, saline, or hydrogen peroxide; some investigators believe that this alone may be therapeutic in many cases of AOE, but this has not been studied adequately. Others believe that lavage should only be done if the tympanic membrane can be fully visualized and determined to be intact, which is rarely possible due to the edema of the canal.

Other methods to clear debris include using a soft-tipped suction device or a cotton swab with the cotton fluffed out, under direct visualization with the otoscope.

Topical medications are then administered. Most medications are combinations of a low pH antiseptic, an antibiotic, and/or a corticosteroid. Examples of antiseptics include aluminum acetate, acetic acid, and boric acid. Common antibiotics include aminoglycosides (gentamicin, tobramycin, neomycin), quinolones (ciprofloxacin, ofloxacin), and polymyxin B. The most common corticosteroids are hydrocortisone and dexamethasone. There have been multiple studies comparing the efficacy of different medications, but most have shown little difference in outcome. One recent meta-analysis of these studies showed no difference in clinical outcomes when comparing antiseptic alone versus antibiotics, quinolone versus nonquinolone antibiotics, and steroid/antibiotic combinations versus antibiotics alone. However, studies have shown that adding topical steroids to the treatment regimen did result in quicker symptom resolution. The lack of difference in outcome suggests that the choice of which agent to use should be based on the patient's preference, cost, and ease of administration.

Systemic antibiotics, while prescribed in 20% to 40% of cases, are generally not recommended for multiple reasons. Most of the oral medications prescribed do not have efficacy against *P. aeruginosa* and *S. aureus*. Adverse effects are much more common with oral antibiotics than with topical preparations. Topical administration of antibiotics allows for concentrations 100 to 1,000 times that of systemic medications. Systemic antibiotics also have a higher risk for selecting out resistant organisms. Systemic antibiotics should be considered only if there is concomitant otitis media or if the patient is not responding to topical preparations.

For most patients, 3 to 4 drops of these medicines should be administered and held in the ear for 3 to 5 minutes. If the external canal is obstructed due to edema, ear wicks composed of cellulose or ribbon gauze can be used to make the administration of the medication more efficacious. If the tympanic membrane is perforated or a tympanostomy tube is present, ototoxic agents, which include the antiseptics and aminoglycosides, should be avoided; the quinolone agents have been approved by the Food and Drug Administration (FDA) for use in these patients.

Pain relief should also be a major goal in treatment of AOE. Mild to moderate pain can usually be controlled with over-the-counter acetaminophen, ibuprofen, or naproxen. More severe pain may require narcotic preparations. Topical anesthetic drops are generally not recommended as they can mask the progression of disease.

Ideally, the patient should avoid water sports for 7 to 10 days, but competitive swimmers are usually allowed to return in 2 to 3 days once pain and drainage are resolved. When they return, they should wear ear plugs and a tight-fitting swim cap to keep moisture out of the ear.

Most cases of AOE will show significant improvement in 48 to 72 hours. If there is no significant improvement by this time, the clinician should reexamine the patient, consider alternative diagnoses, perform aural cleaning, and consider changing medications.

Prevention

There are a number of recommendations to prevent AOE in aquatic athletes and patients who have a history of the disease. The most important method is to make sure to remove all water from the external canal after swimming. This can be accomplished by using a hair dryer on the lowest setting or by using drying and acidifying drops. There are several commercial products available, but many swimmers use a homemade 1:1 mixture of rubbing alcohol and white vinegar, the two main components of the commercial products. Tight-fitting swim caps are also recommended. Some authors recommend the use of ear plugs, while others believe that these can abrade the ear canal and may increase the risk of recurrence of AOE. Other recommendations include avoidance of trauma to the external canal from overaggressive cleaning with cotton swabs and avoiding swimming in polluted bodies of water and pools with inadequate chlorination.

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See also Ear Injuries; Swimming, Injuries in

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Ear Injuries

Sports-related ear injuries are not uncommon and may affect the external, middle, or inner ear. Direct trauma to the auricle commonly occurs in wrestling and rugby and may result in the infamous "cauliflower ear." External ear infection is so common in swimmers that it has come to be referred to as "swimmer's ear." Middle ear injury may involve perforation of the eardrum, and inner ear barotrauma is often associated with diving. In this entry, we will review the evaluation and management of the most common sports-related ear injuries.

Auricular Hematoma

Auricular hematomas result from blunt trauma to the ear, most commonly in contact sports such as boxing, wrestling, and rugby. The skin overlying the anterior ear is thin and tightly adherent to the underlying cartilage, so it does not easily slide over the cartilage when direct force is applied. Instead, there is a shearing force between the perichondrium and the underlying cartilage, and the blood vessels supplying the cartilage are torn. Blood accumulates between the perichondrium and the cartilage, resulting in a hematoma. Complications of the hematoma may include necrosis and infection of the underlying cartilage because of loss of blood supply from the torn perichondrial vessels. Also, the subperichondrial hematoma actually stimulates new cartilage formation, leading to an asymmetric deformity often called "cauliflower ear."

Athletes with an auricular hematoma will present with painful swelling of the external ear and loss of ear landmarks. Timely evaluation by medical staff is important as those athletes who wait several days for treatment are at risk for significant fibrosis, which may require surgical debridement. The key components to treatment are (a) complete evacuation of the hematoma, (b) elimination of the perichondrial dead space, and (c) approximation of the overlying tissues.

The ear is initially anesthetized with 1% or 2% lidocaine and sterilely prepped. A curvilinear incision following the natural curve of the pinna is made using a blade along the entire length of the hematoma. The hematoma is then removed with gentle suctioning. Studies have shown that simple needle aspiration is not adequate in removing the clot. Following evacuation of the clot, the dead space is eliminated using a dental roll, button, or silicone splint, which is fit firmly over the area of the incision. The dental roll or button is sutured in place with through-and-through sutures, and antibiotic ointment is applied to the incision and suture sites. The athlete should return in 1 to 2 days to ensure adequate evacuation of the clot and then have the sutures removed in 7 to 10 days.

Otitis Externa

Otitis externa (OE) is an infection of the external ear canal. Heat, humidity, and water in the ear canal from swimming or bathing are associated with OE; they can cause irritation and breakdown of the protective barrier. Studies have shown that the incidence of OE is nearly 2.5 times greater in swimmers than in nonswimmers, thus leading to the common term *swimmer's ear*.

Early symptoms of OE may include pruritus, otalgia, erythema, and discharge from the ear. Pain may be worsened with manipulation of the auricle or direct pressure on the tragus. In more severe cases, the pain may be accompanied by edema, purulent discharge, and lymphadenopathy. If left untreated, it can progress to malignant (necrotizing) otitis, with concomitant temporal bone osteomyelitis. Examination may reveal a narrowed external canal due to edema, with erythema, debris, and purulent discharge. There is often erythema of the tympanic membrane (TM), which may lead to incorrect diagnosis of otitis media.

The most common causative organism is *Pseudomonas aeruginosa,* accounting for up to 50% of cases in some studies. *Staphylococcus aureus* is the next most common cause, followed by other aerobic and anaerobic bacteria such as *Escherichia coli,* streptococci, *Proteus,* and *Klebsiella.* Fungal causes account for less than 10% of cases but may be more common in patients with diabetes.

Treatment involves cleansing of the ear canal, pain control, and topical antimicrobials. Cleansing is accomplished with gentle irrigation and suction and may be followed by use of acetic acid or isopropyl alcohol to help dry the canal as tolerated. The first-line antimicrobial is usually a fluoroquinolone preparation used twice daily for 5 to 10 days. Most current preparations include a steroid such as hydrocortisone or dexamethasone, which has been shown in some studies to decrease the duration of symptoms by nearly a day. If the OE infection is refractory to topical treatment or becomes severe, a course of oral antibiotics may be warranted. One must also evaluate for fungal superinfection, which can be treated with topical clotrimazole or tolnaftate.

OE in swimmers may be prevented by using swim caps or ear plugs. The ear canal can also be dried by acetic acid or alcohol drops or by using a hair dryer after swimming or bathing. Irritation of the ear canal with cotton swabs should be avoided.

Exostosis

Auditory *exostoses* are bony outgrowths that result from chronic exposure to cold water, often seen in swimmers, surfers, or divers. They are from the temporal bone and protrude into the external canal. They are often found bilaterally, often with multiple bony growths in each ear canal. More severe disease is found in cold-water surfers and is correlated directly with frequency and time of water exposure. These bony growths may result in debris accumulation, pain, hearing loss, or recurrent ear infections since they block the ear canal and prevent its cleansing. Surgical excision is the treatment for those with severe disease. Prevention includes consistent use of earplugs and limiting the duration and frequency of exposure to cold water.

TM Perforation

Traumatic TM rupture may occur when an athlete hits the water with significant force (such as during water skiing) or is struck by a wave, as is commonly seen in surfers. In scuba diving, rupture can occur due to dysfunction of the eustachian tube, which leads to failure to equalize pressures. Patients with recurrent otitis media have an increased risk of traumatic rupture due to scarring of the TM.

The most common complaint is that of ear pain and conductive hearing loss, but patients may also have vertigo, tinnitus, or blood in the external ear canal. Treatment should include topical antibiotic drops to avoid infection. Patients should avoid getting water or any foreign material in their ear until the perforation heals. Most TM ruptures will heal spontaneously within 1 month, but patients should be observed closely to ensure that infection does not develop and unhealed perforations are referred to otolaryngology in a timely fashion.

Barotrauma

Inner ear *barotrauma* is an uncommon complication of diving that may lead to sudden sensorineuronal hearing loss and vertigo. It is caused by damage to the round or oval window by an inability to equalize pressures. Evaluation includes an otologic referral and high-resolution temporal bone CT scan. Treatment may involve diagnostic tympanotomy and sealing of the round and oval window membranes.

Rahul Kapur

See also Ear Infection, Outer (Otitis Externa)

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Eating Disorders

Disordered eating (DE) refers to a wide spectrum of maladaptive behaviors and attitudes about weight, body image, and food. At one end, it may be an unintentional caloric restriction, with fewer calories consumed than required for daily expenditure, thus leading to mild weight loss, slight hormonal disturbances, and a decline in sports performance. At the other end, DE may involve extreme body image delusion and life-threatening behaviors that meet the criteria for psychological diagnosis of an eating disorder such as anorexia nervosa or bulimia nervosa.

Types of Disordered Eating

Anorexia nervosa is defined as a serious life-threatening disorder characterized by deliberate self-starvation, as well as the following:

- Refusal to maintain body weight at or above a minimal normal weight for age and height
- Intense fear of gaining weight or becoming fat, even though underweight
- A disturbance in the way one's body weight/shape is experienced (self-evaluation, denial)
- Amenorrhea (absence of at least three consecutive periods)

Anorexia has two subtypes: (1) a restricting type and (2) a binge-eating/purging type.

Bulimia nervosa is a serious life-threatening disorder characterized by recurrent episodes of binge eating usually followed by self-induced vomiting or some form of purging as a means of controlling weight (e.g., vomiting, laxatives, diuretics, other medications, fasting, and excessive exercise). It also includes the following:

- There is a feeling of loss of control during a bingeing episode.
- The binge eating and inappropriate compensatory behaviors both occur on average two or more times a week for 3 months or longer.
- Self-evaluation is unduly influenced by body shape and weight.
- The bingeing/purging does not occur exclusively during periods of anorexia.

Bulimia is subdivided into purging type (i.e., use of vomiting, laxatives, diuretics, or enemas to rid the body of the consumed calories) and nonpurging type (i.e., use of other inappropriate compensatory behaviors such as fasting or excessive exercise).

Eating Disorder Not Otherwise Specified (EDNOS) is a term used in the American Psychiatric Association's *Diagnostic and Statistical Manual of Mental Disorders,* fourth edition (*DSM-IV*) to encompass eating disorders that do not fall under the more strictly defined "anorexia" or "bulimia." EDNOS includes the following:

- All the criteria for anorexia are met, but the individual has regular menses.
- All the criteria for anorexia are met, but despite significant weight loss, current weight is within the normal range.
- All the criteria for bulimia are met but less frequently than twice a week for 3 months.

In addition, there are some "unofficial" terms that are sometimes used in the sports community:

Anorexia athletica: a subgroup of athletes with eating disorder symptoms that do not permit a diagnosis of anorexia nervosa or bulimia nervosa to be made and would therefore fall within EDNOS.

Orthorexia nervosa: individuals who take their concerns around eating "healthy" foods to dangerous and/or obsessive extremes.

Individuals at Risk for Developing Disordered Eating

While anyone is at risk, some populations have a higher risk of developing DE. These include women, female athletes, athletes in aesthetic and/or weight class sports, athletes started in sports-specific training early in life, those who have experienced transitions (e.g., a new coach, starting college) or traumatic events (e.g., a breakup, parents' divorce, a death in the family), and those who have felt pressure to reduce weight, improve sport performance, look better in uniform, or achieve a body type consistent with societal ideals.

Published prevalence rates of DE vary depending on how the information is collected, but up to 47%

of female high school athletes and 62% of female college athletes have been reported to have DE.

Athletes in particular are often susceptible to DE because of overconformity to the "sports ethic." The sports ethic emphasizes sacrifice for the game, seeking distinction, taking risks, and challenging limits. Although the sports ethic is meant to promote positive concepts, an athlete may strive so greatly that he or she transforms these positive norms into deviant behaviors to be successful. One example is the use of banned substances to get an edge. Another is extreme dietary habits and playing through unhealthy symptoms.

Health Risks of Disordered Eating

Eating disorders have both short- and long-term consequences for health. They include the following:

- Depression and anxiety
- Decreased coordination, balance, and muscle function
- Fluid/electrolyte imbalances
- Acid-base abnormalities
- Anemia
- Heart arrythmias
- Dental caries and esophageal tears in those who repeatedly vomit
- Delayed stomach emptying and constipation
- Osteoporosis and fractures
- Infertility
- Bad lifestyle habits that can lead to full-blown, life-threatening disorders
- Increased suicide attempts
- Six times the mortality rate in anorectics compared with the general population

Recognizing Disordered Eating

A variety of signs and symptoms may suggest DE. These include the following:

- Decreased concentration, energy, muscle function, coordination, and speed
- Increased fatigue and perceived exertion
- Longer recovery time needed after workouts, games, and races
- More frequent muscle strains, sprains, and/or fractures
- Slowed heart rate and low blood pressure
- Reduced body temperature and sensitivity to cold (i.e., cold hands and feet)
- Complaints of light-headedness and dizziness
- Complaints of abdominal pain
- Avoidance of water or excessive water intake
- Preoccupation with food
- Ritualistic eating and/or avoidance of certain foods
- Prolonged or additional training above and beyond that required for the sport (e.g., extra sit-ups and laps)
- Perfectionism
- Excessive concern with appearance
- Personality shifts (e.g., more withdrawn and isolated, acting excessively upbeat in an attempt to mask the problem)

Treatment

Treatment of those with eating disorders usually requires a multidisciplinary approach. This is important for parents, coaches, and patients to remember, as different disciplines bring different areas of expertise in helping an individual recover.

One common approach involves a physician, a nutritionist, and a mental health specialist (e.g., psychologist, psychiatrist). It is important to find out whether the patient can be managed effectively as an outpatient or requires hospitalization, medical supervision, nutrition education, and psychological support. Family members, friends, teammates, coaches, and others can help support the individual who is struggling and try to help keep him or her on track.

How to Get Help for a Person With Disordered Eating

Initially, the individual should be addressed in a private setting without peers around. Behaviors or changes that have become evident should be mentioned while focusing on concern for the individual. People are often resistant to admitting that they have an eating problem and to accepting help. But the earlier an intervention is made, the better the likelihood of a positive outcome. Providing information for the individual to gain some self-awareness is a good beginning. But having professional help early is vital, as most DE is about much more than food and weight.

Prevention Tips for Those Working With Athletes

With society's emphasis on appearance, and the focus of some sports on leanness and/or aesthetics, it is understandable that many athletes develop DE. There are some sports that have weight requirements (e.g., wrestling, lightweight rowing). But a transparent protocol should be developed to make the weigh-in procedures as stressfree as possible. These include preseason athlete assessment to determine if certain weight categories are realistic for an individual. This should be done by someone other than the coach (e.g., trainer, nutritionist). Weight goals should be presented early on, without changing target weight for athletes. Coaches should not provide unhealthy weight loss tips. Whether coaching weight-restricted or open-weight sports, coaches should minimize focus on appearance and weight and instead emphasize performance and health.

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See also Dysmenorrhea; Female Athlete Triad; Menstrual Irregularities

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Elbow, Osteochondritis Dissecans of the

Osteochondritis dissecans (OCD) *of the elbow* is an acquired injury to the outer end of the humerus (arm bone) in the elbow joint. The part of the humerus most commonly injured is called the *capitellum*. The OCD lesion occurs in the bone directly underneath the cartilage of the capitellum and can be thought of as a stress fracture to a small area of the bone. After the injury, this area of the capitellum is not strong enough to support the cartilage over the top of it. If the injury progresses, eventually the cartilage over the top of the OCD can crack. OCD of the elbow is most commonly seen in gymnasts and baseball pitchers, who place high stress on their elbows during sports. Elbow OCD does not usually result from a single injury but is thought to be an overuse syndrome occurring from repetitive microtrauma to the capitellum.

Anatomy

The elbow joint is the space between the humerus and the two forearm bones: the radius and the ulna. The inner portion of the humerus and the ulna form a hinge joint at the inner aspect of the elbow (near the body). The outer portion of the humerus is called the *capitellum,* and it directly contacts the radius at the outer portion of the elbow joint (away from the body). The bone directly underneath the cartilage in the elbow is called the subchondral bone, and its purpose is to support the cartilage lying over it. It is the subchondral bone that initially gets injured in the OCD of the capitellum.

Causes

OCD of the elbow most commonly occurs in gymnasts and baseball pitchers in the capitellum portion of the humerus. Gymnasts use their arms as weight-bearing joints while doing handstands and handsprings. Because the elbow is shaped so that it is angled inward (points in toward the body with palms up and arms extended), the compression force of a handstand or handspring is concentrated on the outer aspect of the elbow joint. Repetitive microtrauma from thousands of handstands can cause a small stress fracture to develop in the subchondral bone of the capitellum. This is the first stage of elbow OCD.

For baseball pitchers, the pitching motion places tremendous stresses at the elbow joint. During a pitch, the inner aspect of the elbow (humerus-ulna part of the elbow joint) experiences a distraction force, while the outer aspect of the elbow (capitellum-radius portion of the elbow joint) experiences a compression force. Similar to a handspring, the pitching motion places a repetitive compression force across the capitellum. After thousands of baseball pitches, a pitcher can acquire a stress fracture in the subchondral portion of the capitellum. If pitching continues, the injured capitellum will eventually lose its blood supply and will no longer be able to support the cartilage over the top of it. Over time, this cartilage can crack and break loose.

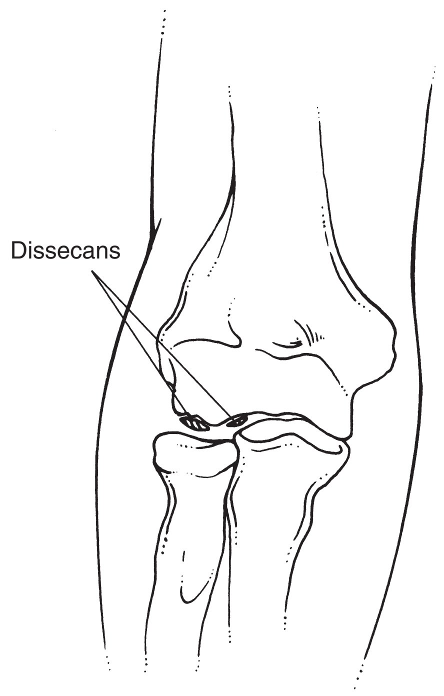

Figure 1 Osteochondritis Dissecans of the Elbow

Note: Loose or detached bodies in the elbow joint occur with powerful, repetitive motions that place stress on the joint, as in gymnasts and baseball pitchers.

Symptoms

OCD of the elbow occurs in gymnasts, baseball pitchers, and other overhead athletes aged 12 to 16 who present with aching elbow pain at the outer part of the elbow, which is worse with activity. If the cartilage over the OCD lesion is cracked and injured, the elbow will often swell. At this stage, the athlete is usually unable to fully extend the elbow. Mechanical symptoms such as catching or locking in the elbow may also be noted.

Diagnosis

A gymnast or baseball pitcher who presents with elbow pain with throwing or handstands may have an OCD of the elbow. On physical exam, the elbow joint is carefully inspected to look for signs of swelling. The outer aspect of the elbow is palpated for tenderness. The patient is asked to fully flex and extend the elbow, and the motion is compared with the other elbow.

On an X-ray, the OCD lesion can appear as an irregularity in the subchondral bone of the capitellum (see Figure 1). Since many OCD lesions of the elbow are not seen on an X-ray, a magnetic resonance imaging (MRI) scan is often obtained when the diagnosis is suspected. The MRI scan helps determine if the cartilage over the lesion is intact or cracked. If the cartilage is cracked, there will often be joint fluid underneath the lesion, which can be seen easily on the MRI scan. An MRI scan may also be useful in identifying any loose bodies (broken-off pieces of cartilage) in the elbow that may not be seen on an X-ray.

Like OCD of the knee and ankle, OCD of the elbow is also classified as "stable" or "unstable." Stable lesions involve only the subchondral bone; the overlying cartilage is not broken. In unstable lesions, the overlying cartilage is cracked. Making this determination is important because stable lesions tend to heal well with rest and activity restriction. Unstable lesions do not heal as well and if left untreated can completely break off, forming a "loose body."

Treatment

As with OCD in other joints, the most important factors involved in planning treatment are the age of the patient and the stability of the lesion. In general, most stable lesions in younger children who are still growing heal without surgery. For partially unstable lesions in growing children or for stable lesions in patients who are already grown, a short period of nonsurgical management is often attempted. However, if the OCD lesion does not heal after 3 to 6 months, then surgery is recommended. Unstable OCD lesions and most lesions in patients who have finished growing are treated with surgery.

Nonsurgical Treatment

The most important principle for nonsurgical treatment of elbow OCD is to stop the repetitive activities that are causing pain. For baseball pitchers, this means no throwing. For gymnasts, this implies no weight-bearing activities on the arms. Bracing or immobilization of the elbow may be necessary for a short period of time if the pain is significant. Compliance with these measures is often difficult in high-level athletes.

Activity restrictions are continued for at least 3 months. During this time, the physician may obtain serial X-rays to check for healing of the lesion. After 3 months, activities are gradually increased, with a planned return to pitching (for baseball players) or handstands (for gymnasts) at approximately 6 months after the diagnosis. Full healing of the lesion can often take anywhere from 3 to 12 months.

Surgery

Surgery is recommended for unstable OCD lesions and for lesions that do not heal after an appropriate period of nonsurgical management. Surgical intervention commonly involves elbow arthroscopy, although sometimes a larger incision may be necessary. During arthroscopy, the surgeon will directly look at and feel the cartilage over the top of the lesion on the capitellum. Depending on the appearance and feel of the cartilage over the lesion, the surgeon will decide how to proceed.

In some cases, the cartilage over the lesion will appear normal (with no cracks) but will feel like a softened mass. In these cases, the surgeon may drill tiny holes through the cartilage and across the OCD lesion. This technique is called *transarticular drilling*. The idea is to stimulate the underlying subchondral bone to bleed, which will allow it to heal. If the lesion is very large or if the cartilage is partially cracked, the surgeon may also perform internal fixation. In these cases, metal or bioabsorbable screws or bone pegs are placed across the lesion to provide stability and compression.

In some cases, the cartilage will be completely destroyed over the lesion or would have broken off to form a loose body. In these cases, the surgeon will often just remove the cartilage. The underlying subchondral bone will then be exposed. The surgeon may then elect to perform a *microfracture procedure,* in which a tiny pick is used to create small holes in the subchondral bone. These holes will bleed, and a blood clot will eventually form over the OCD lesion. Over time, the blood clot can repair the lesion with a fibrous form of cartilage. Newer cartilage transplantation techniques are often reserved for patients who have already had the microfracture procedure done but still have pain.

After Surgery

After surgery, the patient may initially be placed in an elbow brace to limit movement. Elbow motion is slowly increased over time. Physical therapy is often initiated to help the patient regain elbow motion and strength. The patient is not allowed to resume sports activities until the lesion is felt to have healed. This can take anywhere from 3 to 12 months. Return to overhead sports is difficult for some athletes following this procedure. Baseball pitchers may need to switch positions to be able to compete without pain. Some gymnasts are unable to return to their previous level of play after this injury.

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See also Ankle, Osteochondritis Dissecans of the; Knee, Osteochondritis Dissecans of the; Sports Injuries, Surgery for

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Elbow and Forearm Injuries

Injuries to the elbow and forearm can result from acute trauma as well as overuse. Acute traumatic injuries, such as fractures and dislocations, usually result from a fall on an outstretched hand/arm (FOOSH). In children, forearm fractures account for greater than 50% of all fractures in the pediatric age-group. Acute injuries can occur in any sport where falls on the outstretched hand are common, including basketball, football, soccer, and track-and-field events.

Overuse injuries of the elbow and forearm are common in sports that use the upper extremities and require repetitive training, such as weight lifting, golf, tennis, and gymnastics. These injuries are also seen commonly in throwing sports, such as baseball and softball.

Anatomy

The radius and ulna are the bones in the forearm, with articulations proximally and distally. The elbow joint comprises the articulations between the radius, ulna, and humerus. The distal humerus has two main articulating surfaces, namely the *capitellum,* which articulates with the radial head, and the *trochlea,* which articulates with the coronoid and olecranon of the ulna. The elbow joint has three articulations: (1) the proximal radioulnar joint, (2) the radiocapitellar joint, and (3) the ulnohumeral joint. The radioulnar and radiocapitellar joints allow supination and pronation of the forearm, with the radius pivoting around the ulna. The ulnohumeral joint allows flexion and extension of the elbow. Stability of the elbow is provided by the bony hinge below 20° and greater than 120° of flexion. Between 20° and 120° of flexion, the ligaments and capsule are the main stabilizers of the elbow (Figure 1).

The elbow develops from multiple ossification (new bone formation) centers, which makes the elbows of children and adolescents vulnerable to injuries such as fractures and apophyseal injuries. The growth plates at the ossification centers are susceptible to traction or shearing forces. The ossification centers follow a predictable order of formation, allowing for determination of bony maturity, based on their radiographic appearances. The order of appearance is as follows: Capitellum (age 1–2 years),

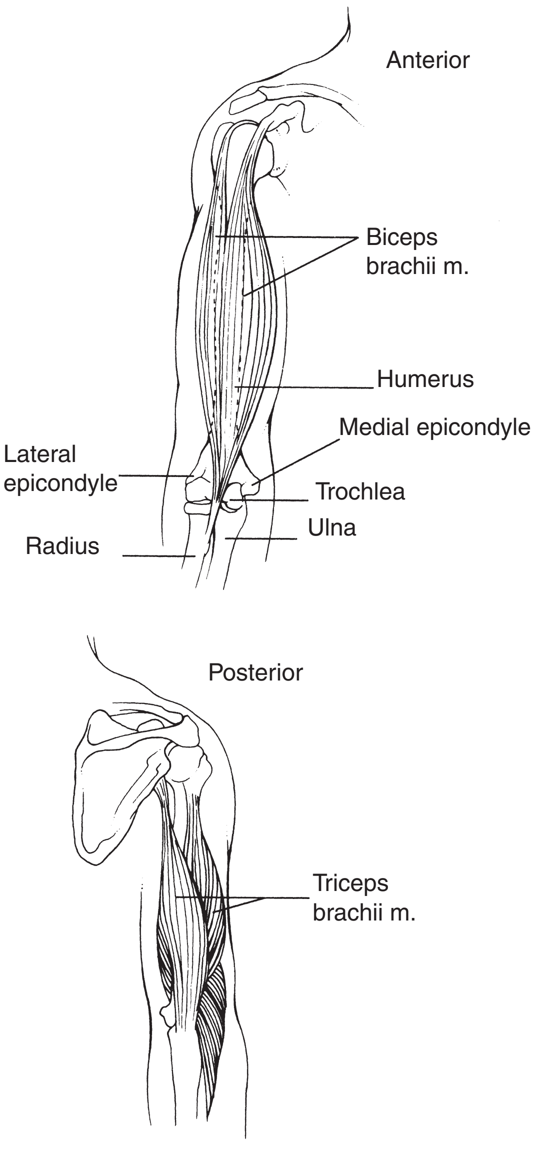

Figure 1 Anatomy of the Elbow

*R*adial head (age 3 years), *I*nternal (medial) epicondyle (age 5 years), *T*rochlea (age 7 years), *O*lecranon (age 9 years), and the *E*xternal (lateral) epicondyle (age 10 years in girls and 11 years in boys) (mnemonic "CRITOE"). Most (80%) of the growth of the humerus occurs proximally, so there is less remodeling potential at the elbow when fractures occur there.

There are three ligaments composing the ulnar collateral ligament (UCL) complex on the medial aspect of the elbow: anterior oblique, posterior oblique, and transverse. The anterior oblique ligament is divided into anterior and posterior bands. The anterior band of the anterior oblique ligament provides most of the stability of the elbow. It is most prone to injury from acute or repetitive valgus strain.

The lateral collateral ligament (LCL) complex on the radial aspect of the elbow comprises four ligaments: (1) the radial collateral ligament (RCL), (2) the lateral ulnar collateral ligament (LUCL), (3) the accessory lateral collateral ligament (ALCL), and (4) the annular ligament (AL), which wraps around the radial head. The LCL complex functions to stabilize the elbow against varus and external rotatory stress. The LUCL helps control posterolateral rotatory motion in the elbow. Rotatory instability in the elbow is caused by injuries to the LCL at the humeral insertion, primarily of the LUCL and RCL.

The biceps, brachialis, brachioradialis, and triceps muscles compress the elbow joint and provide stability. The lateral elbow is stabilized by the extensor and the supinator muscles. The common extensor muscle group, which inserts on the lateral epicondyle, consists of the extensor carpi radialis brevis, the extensor digitorum, the extensor digiti minimi, the extensor carpi ulnaris extensor pollicis, and the supinator. The deep extensors of the forearm originate from the ulna and the radius and include the supinator, the abductor pollicis longus, the extensor pollicis longus and brevis, and the extensor indicis. The medial elbow is stabilized to a small degree by the flexor-pronator muscle group. The common flexor muscle group consists of the pronator teres, the flexor carpi radialis, the palmaris longus, and the flexor carpi ulnaris. The deep flexors of the forearm include the flexor digitorum superficialis and profundus, the flexor pollicis longus, and the pronator quadratus.

Three main nerves supply the elbow and forearm: the ulnar, median, and radial nerves. The ulnar nerve has a superficial course, passing behind the medial epicondyle and lying over the UCL and anteriorly to the medial triceps muscle. The ulnar nerve is fairly mobile, which allows it to slip out of the cubital tunnel in some people. Because of its superficial course, the ulnar nerve is the most commonly injured neurological structure in sports. The median nerve courses under the ligament of Struthers in the medial arm alongside the brachial artery, into the antecubital fossa medial to the biceps muscle, and under the pronator teres and bicipital aponeurosis. The radial nerve travels from the posterolateral arm at the level of the distal third of the humerus toward the anterior aspect of the elbow. The radial nerve divides into the superficial radial nerve and the deep branch, the posterior interosseous nerve, which supplies the extensor muscles of the forearm. The posterior interosseous nerve runs close to the radial neck and under the supinator, passing the arcade of Frohse, where it can be compressed.

Evaluation of Injuries

Details of Injury

Important details to obtain from an athlete with an elbow or forearm injury include the patient's age, the dominant hand, the sport and position played, and which arm is injured. Additional details should include the duration of symptoms and what the actual complaint is, whether it is pain, instability, or lack of function. Throwing athletes may complain that they are unable to throw the ball as far or as accurately as before injury. Athletes in sports such as volleyball or tennis may complain that they are unable to hit the ball as hard. The presence of mechanical symptoms such as catching or locking may suggest an injury to the joint, such as osteochondritis dissecans (OCD), a bony injury, or a loose body. The presence and distribution of neurological symptoms such as weakness or paresthesias may suggest an injury to the neck, brachial plexus, or peripheral nerves.

Determining the mechanism of injury is very important to help narrow the type of injury. Acute traumatic injuries, such as a fall on an outstretched hand, result in different injuries from those with a more gradual onset resulting from repetitive overuse. Obtaining details regarding alleviating and aggravating factors/activities can also help narrow the differential diagnosis. Elbow instability usually occurs with hard throwing or with activities involving weight bearing on the arms, such as gymnastic maneuvers or push-ups. For throwing athletes, additional details to note include the style of throwing, the types of throws/pitches, the volume of pitches/throws, the velocity and accuracy of throws, and any training errors, as well as which phase of throwing produces symptoms. Pain that occurs during cocking and late acceleration is consistent with ulnar-sided injury resulting from valgus stress to the elbow. Symptoms that occur during deceleration and follow-through suggest posterior impingement and stress injuries. Localizing the symptoms can help focus on the most probable diagnosis. For instance, posterior elbow pain usually occurs during hyperextension.

Physical Findings

With injuries to the elbow or forearm, there may be swelling, bruising, or deformity of the arm. The athlete may be unwilling to move the arm and may hold the arm in various positions to minimize pain. For instance, an injured athlete may hold his or her arm straight and not want to bend it. A *joint effusion* (fluid in the joint) may result in loss of the indentations next to the olecranon.

The point of maximal tenderness to palpation of the elbow and forearm can help localize the injured structure. Bony tenderness usually indicates a fracture or other bony injury. Tenderness of muscles may indicate a muscle injury or muscle spasm.

The elbow can move in the following directions: flexion, extension, and forearm supination and pronation. Flexion should be from 0° to 145° ± 10°, pronation at about 80°, and supination at about 85°. Injuries may result in decreased range of motion of the elbow and forearm. Decreased extension is suggestive of a chronic flexion contracture or an injury to the joint. The wrist can be flexed and extended. Range of motion of the wrist can also be decreased with injuries to the elbow and forearm.

There are a number of special stress tests that can assess the functional integrity of the UCL (medial aspect) in an athlete with an injured elbow. These tests include the valgus stress test, the milking maneuver, and the moving valgus stress test. The valgus stress test should be performed with the elbow flexed to 30°. The patient's hand and wrist are fixed between the examiner's arm and body, and a valgus stress is applied to the elbow. The milking maneuver is performed with the elbow flexed to 70°. The examiner supports the patient's elbow with one hand and applies a valgus force to the elbow by tractioning the patient's thumb, similar to milking a cow. By placing the elbow in this position, the valgus throwing position is re-created, keeping the shoulder externally rotated, which reduces the effect of shoulder rotation on UCL assessment. The moving valgus stress test is performed with the shoulder abducted to 90°. The examiner applies a valgus (toward the midline) stress to the elbow as the shoulder is fully externally rotated. The examiner maintains the valgus force while quickly extending the elbow to about 30°, similar to the acceleration phase of throwing. A positive test reproduces pain at the UCL. The pain usually occurs maximally between 120° and 70° of flexion as the elbow is extended.

Certain injuries to the elbow can result in instability of the elbow. Varus laxity (instability of the lateral elbow) is very uncommon. Varus stress testing is performed by applying a varus (away from midline) force to the lateral elbow while flexing the elbow to 30° with the forearm in full pronation. A positive test reproduces pain or laxity in the lateral elbow. Posterolateral (behind) instability of the elbow can be assessed with the lateral pivot shift apprehension test. The pivot shift test is performed with the patient lying supine. The injured arm is placed overhead with the elbow in supination while the examiner applies a valgus and axial force to the elbow. A positive test causes pain or a sense of apprehension. With the elbow in extension, the elbow is then flexed, noting any reduction "clunk," which usually occurs between 40° and 70° of flexion. A reduction clunk indicates posterolateral instability, as the radial head moves backward when the elbow rotates around the axis of the UCL.

The valgus extension overload test evaluates potential impingement of the elbow. The test is performed by placing the athlete's arm quickly in maximal extension with the forearm pronated. While the elbow is hyperextended, a valgus force is applied. Pain caused by this maneuver is consistent with posterior impingement of the olecranon in the olecranon fossa.

Tendinopathies can be identified with resisted muscle testing. Resisted forearm supination, wrist extension, or third-digit extension with the elbow in full extension causing pain over the lateral epicondyle may indicate an injury to the common extensor tendon. Symptoms of lateral epicondylosis can also be reproduced with passive palmarflexion while the elbow is extended. Symptoms of common flexor tendinopathy may be reproduced by resisted wrist palmarflexion or pronation and passive wrist dorsiflexion/extension with the elbow extended. Grip strength is another resisted muscle test to assess pain.

Injuries to the neck or shoulder may cause elbow or forearm pain. In athletes with elbow and forearm injuries, the neck, bilateral shoulders, elbows, and wrists should be assessed to rule out other injuries. There may be decreased muscle strength and possibly neurological abnormalities, such as numbness or tingling. Other factors may contribute to elbow or forearm injuries, such as poor core trunk stability, weakness of the leg muscles, weak shoulder muscles, and poor shoulder and scapular movement.

Investigations

X-rays of the elbow and forearm should be obtained in instances of acute trauma where fractures are suspected. Standard views include anterior-posterior (AP), lateral, and oblique. Some fractures may not be obvious on X-rays (occult). A posterior fat pad sign may indicate an occult joint fracture in children with otherwise normal X-rays. In chronic elbow pain, X-rays may indicate OCD, arthritis, or calcification in the muscle (myositis ossificans).

A computed tomography (CT) scan can give more bony definition and can indicate occult fractures. A bone scan can indicate stress fractures of the olecranon or medial apophysis. Bone scanning can also help determine bony activity and assess the healing potential of OCD. Magnetic resonance imaging (MRI) is the gold standard for soft tissue injuries, although ultrasound can be useful as well. MRI is being used more frequently for identifying stress fractures and occult fractures without radiation. A magnetic resonance (MR) arthrogram can diagnose complete and partial tears of the UCL.

Prevention of Injury

Types of injuries that can be seen in the elbow are shown in Table 1. Table 2 indicates the types of

Table 1 Elbow Injuries

Lateral Elbow	*Medial Elbow*	*Posterior Elbow*
Extensor tendinopathy	Flexor/pronator tendinopathy	Olecranon bursitis
Referred pain (cervical spine, upper thoracic spine)	Ulnar collateral ligament sprain	Triceps tendonitis
Synovitis of radiohumeral joint	Ulnar nerve compression	Posterior impingement
Radiohumeral bursitis	Avulsion fracture of the medial epicondyle (adolescents)	Dislocation
Posterior interosseous nerve entrapment (radial tunnel syndrome)	Medial apophysitis (adolescents)	Supracondylar fractures (children)
Osteochondritis dissecans (capitellum, radius)		Olecranon fracture
Panner disease		Olecranon stress fracture
Radial head fracture		Posterolateral rotator instability

Table 2 Forearm Injuries

Fractures of radius and ulna
Dislocations Monteggia injury (fractured ulna with dislocated radial head at elbow joint) Galeazzi injury (fractured radius with dislocated ulnar head at wrist joint)
Stress fractures
Forearm compartment pressure syndrome

forearm injuries. Prevention of elbow injuries can be achieved by learning the proper technique for a given sport. In throwing sports, athletes should be taught to use the kinetic chain and employ the power of the lower extremities to help add power to their throws. By taking a stride with the leg, athletes can transfer the power of the lower body to the arm. Athletes need to keep the elbow up when throwing to avoid losing power in their throws and to avoid having to "use more arm" to improve speed.

Modification of training risk factors, such as the type and volume of activity, can help prevent injuries, particularly in growing athletes. The amount of training should be gradually increased, in frequency, intensity, and duration, to avoid overuse injuries. The rules of the sport should be enforced by referees and coaches to avoid reckless play and dangerous training practices. In gymnastics, injuries can be minimized by using thicker mats, having spotters next to equipment to help prevent falls, and teaching athletes proper falling techniques.

In younger athletes, particular restrictions can help prevent injuries. For instance, in young baseball pitchers, pitches should be limited to less than 80 pitches per game, participation in one sport should be limited to no more than 8 months of competition per year, and breaking pitches should not be started until after 13 years of age. Adequate rest and recovery—at least 3 days between games—should be allowed to avoid fatigue and overuse injuries.

Preparticipation physicals can identify any muscle imbalances or previous injuries that may not have been fully rehabilitated. Targeted interventions can help resolve these issues. A proper strength-and-conditioning program for athletes participating in sports requiring use of the arms should include exercises to stretch the shoulder and elbow and strengthening of the rotator cuff and periscapular stabilizing muscles. Lower body and core strengthening is also important to prevent injuries to the elbow and forearm.

Return to Sports

In general, following an elbow or forearm injury, an athlete should have full, pain-free range of motion before returning to sports. Return to sports should be gradual, with progressive increase in activity.

Depending on the type of injury, a variable amount of time off from sports is required. If surgery is required, athletes may be off for up to a year. Some athletes may not be able to return to their sport after surgery. In athletes with OCD, ideally radiographic healing should be evident prior to return to sports, although this is not always possible. Athletes, especially overhead athletes, should be completely asymptomatic with all activities before returning to play. After traumatic injuries, such as fractures, there should be radiographic evidence of healing and return of full strength before returning to sports. After traumatic dislocations, most athletes will not resume upper extremity training for at least 3 months. For soft tissue injuries, such as tendinopathies, a period of rest allowing symptoms to resolve is indicated in addition to therapy. Activity can be resumed when symptoms improve.

Laura Purcell

See also Elbow and Forearm Injuries, Surgery for; Elbow Dislocations; Elbow Fractures; Elbow Sprain

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Elbow and Forearm Injuries, Surgery for

The elbow and forearm are particularly important in throwing and overhead sports such as baseball, softball, and tennis. Occasionally, due to overuse or a traumatic injury, athletes may experience forearm or elbow pain, which prevents them from sports participation. Many of these injuries resolve after being treated conservatively with rest and rehabilitation. However, certain injuries require surgery to enable the athlete to return to his or her sport painfree. The goal of surgery in the elbow and forearm is to help athletes return to the level of sport that they were at prior to their injury. Surgery on the elbow and forearm is never done for the sole purpose of improving athletic performance; instead, surgery focuses on restoring the native anatomy and relieving pain.

Anatomy

The elbow joint is the space between the humerus and the two forearm bones: the radius and the ulna. The inner portion of the humerus and the ulna form a hinge joint at the inner aspect of the elbow (near the body). The outer portion of the humerus is called the *capitellum,* and it directly contacts the radius at the outer portion of the elbow joint (away from the body). Ligaments help support the elbow, connecting the humerus to the ulna and radius. The *ulnar collateral ligament* is a major elbow ligament that is located on the inner aspect of the elbow joint (near the body). The ulnar collateral ligament can be injured in pitchers and throwing athletes and may need to be surgically reconstructed if it does not heal on its own.

Muscles run from the humerus to the radius and ulna and to the bones of the hand. These muscles help flex, extend, and rotate the forearm and wrist. Occasionally, the muscle attachment on the outside of the elbow (away from the body) becomes irritated and inflamed. This condition is common in tennis players and is known as *lateral epicondylitis*, or "tennis elbow." Sometimes the muscles of the forearm swell in size while the athlete is exercising. This swelling can cause an increase in the fluid pressure inside the muscle compartment and cause pain and limitation of activities. This condition is called *forearm exertional compartment syndrome* and rarely may require surgery to release the tight covering of the muscles called the forearm fascia.

"Tommy John" Surgery

"Tommy John" surgery involves reconstruction of the ulnar collateral ligament of the elbow. This surgery got its name because it was initially performed in 1974 by Dr. Frank Jobe on a major league pitcher named Tommy John. After he underwent the surgery, Tommy John was able to pitch in more than 150 major league baseball games.

Ulnar collateral ligament tears usually occur in baseball pitchers, but they can also occur in tennis players, football quarterbacks, and javelin throwers. The ulnar collateral ligament is located on the medial epicondyle or inside the elbow and is the most important ligament in providing elbow stability during throwing. When the ulnar collateral ligament is injured, the athlete experiences pain on the inside of the elbow and often is unable to pitch or throw at high velocities.

Ulnar collateral ligament reconstruction surgery is performed through an incision on the inside part of the elbow. The old ulnar collateral ligament has poor healing potential and is replaced with a new transplanted ligament. The new transplanted ligament is usually obtained from the athlete's forearm, thigh, or foot (using a tendon that is not necessary for normal function). This tendon is transplanted over the old ulnar collateral ligament by looping it through holes in the bone of the humerus and the ulna. After surgery, the elbow is placed in an elbow brace, and the athlete begins the long process of rehabilitation. At approximately 1 year after surgery, the athlete may be able to return to pitching or throwing. Today, there are many major league pitchers who have pitched successfully after undergoing this procedure.

Elbow Arthroscopy

As with other joints, arthroscopic surgery can be performed on the elbow. Elbow arthroscopy is often done on baseball pitchers to remove loose pieces of cartilage called "loose bodies" in the elbow. It involves making portals (small holes) on the outside and inside part of the elbow, which connect into the elbow joint. A small camera is placed through a portal and is used to look inside the elbow joint. The anatomy of the elbow is evaluated, and if needed, small instruments can be placed in the elbow using a different portal. These instruments can be used for many purposes, such as to smooth bone spurs, to remove loose pieces of cartilage, or to loosen a tight, contracted elbow joint. Elbow arthroscopy often gives athletes relief from their elbow pain and may help improve range of motion in the elbow.

A condition called *osteochondritis dissecans* occurs in the elbow in gymnasts and baseball pitchers. Osteochondritis dissecans is similar to a stress fracture and affects a small area of cartilage of the elbow and the bone underneath it. With the help of elbow arthroscopy, the surgeon can treat osteochondritis dissecans without needing to make a large incision. This helps protect against infection and may also help athletes maintain range of motion in their elbow after surgery. The surgeon can use elbow arthroscopy to identify the osteochondritis dissecans lesion and either remove the injured cartilage or drill holes in the lesion to stimulate a healing response.

Biceps Tears

Biceps tears occur near the elbow joint and may occur in weight lifters and contact athletes. When the biceps is torn, the athlete loses elbow flexion strength and supination strength (the ability to rotate the forearm in the same direction, as when opening a doorknob). Biceps tears are often treated with surgical repair by making one or two incisions near the elbow crease to help the surgeon find the torn biceps and join it back to the radius bone, where it normally attaches. If the biceps tear is repaired quickly after it is injured, the athlete has a better chance to regain strength and elbow motion. At about 6 months after surgical repair, the athlete is able to resume normal activities.

Lateral Epicondylitis (Tennis Elbow)

Tennis elbow is a condition seen not just in tennis players but in all types of athletes. The condition is caused by inflammation in the wrist extensor muscles where they attach to the humerus. Pain occurs in the outside part of the elbow joint. Athletes often have pain with activities requiring extension of their wrist, such as a backhand stroke in tennis. Nonsurgical treatment most commonly results in significant improvement of tennis elbow. This includes rest, counterforce bracing, and physical therapy directed at stretching and strengthening the wrist extensor muscles. Counterforce bracing involves placing a strap on the arm just below the lateral epicondyle of the elbow. This strap takes the tension off the area on the outside of the humerus where the wrist extensor tendons attach to the lateral epicondyle.

In some cases, tennis elbow pain does not improve even with all the above treatment modalities. If pain persists, the athlete may elect to undergo surgical treatment. Some surgeons are able to relieve this condition by using elbow arthroscopy to debride (clean) the injured or abnormal wrist extensor muscle mass. More commonly, other surgeons will make a small incision in the area of the lateral elbow and remove a very small part of the abnormal muscle tissue while rubbing the elbow bone to cause bleeding and stimulate healing and formation of new tissue in this area. The athletes are usually able to return to sports 2 to 3 months following surgery, after a period of physical therapy designed to increase strength and range of motion in the elbow.

Forearm Exertional Compartment Syndrome

Forearm exertional compartment syndrome is rare but does occur in motorcross athletes and weight lifters. The motorcross athlete experiences extreme pain and fullness in the forearms when grasping the grips on the handlebars of the motorcycle. If it is severe enough, the athlete may begin to experience weakness, numbness, and tingling while riding. In these cases, surgery may be necessary to improve the condition.

To diagnose this condition, the pressure must be checked inside the forearm muscle compartment of the athlete. The sports medicine physician places a special pressure gauge needle in the athlete's forearm muscles both before and after the athlete exercises to determine if the pressure becomes significantly elevated after exercise. If exercise causes a large increase in the pressure inside the forearm muscles, then surgery is considered. During surgery, the pressure in the forearm muscle is decompressed by making an incision on the forearm and releasing the fascia or covering over the forearm muscles. This creates more room for the muscles to expand, leading to decreased pressure on the muscles following activity. When this pressure is decreased, the athlete no longer experiences discomfort and can usually return to normal activities in about 6 weeks.

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See also Elbow and Forearm Injuries; Tennis Elbow

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Elbow Bursitis

A *bursa* is a small, fluid-filled sac, similar to a slippery water balloon, located at places in the body that are subject to excessive friction. When a bursa becomes inflamed or irritated, it responds with more fluid, resulting in pain due to increased pressure on the surrounding tissue.

Anatomy

The olecranon bursa resides at the elbow joint between the skin and the olecranon process of the ulna. Its function is to reduce friction between the skin and the olecranon process when the elbow is placed through a range of motion, mainly during flexion.

History

The most common complaint of a patient with olecranon bursitis is swelling or fullness of the bursae. Sometimes patients will complain of pain and warmth, but mainly they will have some tightness with flexion of the elbow. If there is significant pain and it is accompanied by redness and warmth, the bursa could also be infected. Often the bursa gets inflamed from a trauma, perhaps from landing on the elbow during sports or from external impact such as being tackled in a contact sport. It may also occur from leaning on the elbows on a hard surface for an extended period of time. Patients rarely have accompanying fevers.

Physical Exam

The examiner will find fullness/swelling overlying the olecranon. The area may be red and hot as well. One must take care to look for breaks in the skin or other signs of possible infectious sources. Red streaking on the skin may signify an overlying cellulitis.

Treatment

Treatment commonly involves minimizing the stress and forces to the area and the application of compression and ice. If there is concern about infection, the area should be sterilely prepared and the fluid aspirated, which should then be sent to the laboratory for cultures and sensitivities. Antibiotics should be started. If there are no signs of infection, the bursae can often be left alone.

Aspiration and injection of a corticosteroid to the bursae is another option, but it may be a little aggressive for this relatively benign process. If the patient is having severe pain, then an aspiration and injection may be warranted. Corticosteroids should never be injected into a bursa that is potentially infected. The risk of infection is higher for this superficial bursa than for other bursae. In the case of a severely infected bursa that does not improve quickly, the patient may need surgical intervention for a washout of the infection.

Conclusion

Patients with olecranon bursitis may always have a little residual swelling overlying the olecranon process thereafter. Often they may feel little nodules within the bursae as well. The risk of reinjury is increased, so care must be taken to avoid resting the elbows on hard surfaces or a repetition of the traumatic injury.

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See also Bursitis; Elbow and Forearm Injuries; Sports Injuries, Overuse

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Elbow Dislocations

In children, the elbow is the most common dislocated major joint, whereas in adults, the elbow is the second most common, after the shoulder. Dislocations represent about 10% to 25% of all elbow injuries. Like other upper extremity injuries, elbow dislocations can occur from direct trauma, a FOOSH (fall on an outstretched hand) injury, or a strong directional or levering force on the elbow. Elbow dislocations typically occur in children older than 13 years, after the physes around the elbow are closed. Before this age, the physes are open and are the weakest point in the elbow. Therefore, traumatic forces tend to cause Salter Harris fractures rather than dislocations in young children. However, it is not uncommon to sustain a combined elbow fracture and dislocation. The highest incidence of elbow dislocations occurs in the under-20 age-group, and the majority are associated with sports activity.

Anatomy

The elbow is one of the most complex joints in the body, consisting of three articulations: ulnotrochlear, radiocapitellar, and proximal radioulnar. Elbow flexion/extension occurs mainly at the ulnohumeral and radiocapitellar articulation, whereas forearm pronation/supination involves the radiocapitellar and proximal radioulnar articulation. Normal range of motion (ROM) of the elbow is approximately 150° of flexion to 0° of extension, 90° of forearm pronation, and 90° of forearm supination. The elbow provides attachment sites for various muscle groups and ligaments. The primary stabilizers of the elbow are the ulnotrochlear articulation, the medial collateral ligament (MCL), and the lateral collateral ligament (LCL). The radial head and surrounding muscle bundles make up the secondary stabilizers of the elbow. The elbow joint is extremely congruent and stable due to the specific pattern in which each bone contacts and conforms to other structures within the elbow. Due to the configuration of these interactions, elbow fractures and/or dislocations need to be treated to near-anatomic alignment; otherwise, there can be a high complication rate. Complications include loss of ROM, structural instability, nerve palsies, and muscular weakness.

Clinical Evaluation

Elbow dislocations on physical examination may have an obvious deformity, diffuse joint pain and swelling, decreased or painful ROM, and crepitus. The normal anatomic triangle that is formed by the radial head, lateral epicondyle, and distal lateral tip of the olecranon process is disrupted with elbow dislocations. Any athlete who sustains trauma to the upper extremity and presents with any of those signs or symptoms should be evaluated for the possibility of an elbow fracture or dislocation. With such injuries, the examining physician must also assess the entire upper extremity for associated injuries. The force from a FOOSH injury can be transmitted from the hand up to the clavicle.

Several major nerves and vessels that traverse the elbow can be damaged or tethered. The radial nerve courses over the lateral epicondyle and radial head. Radial nerve function can be tested with middle-finger extension and sensation over the dorsal aspect of the thumb. The ulnar nerve sits within the ulnar groove between the medial epicondyle and olecranon and can be tested with finger abduction/adduction and sensation over the little finger. The median nerve courses over the anteromedial aspect of the distal humerus and elbow joint. Decreased sensation at the tips of the index or middle finger and/or decreased pinch strength with the thumb and index finger can indicate a median nerve injury. The brachial artery can also be injured as it travels with the median nerve across the elbow, after which it branches into the radial and ulnar arteries. Angiography may be needed if distal pulses are absent or diminished compared with the contralateral limb. Vascular injuries and forearm compartment syndrome are rare but have devastating consequences if missed. Any patient with neurovascular compromise should prompt more urgent intervention and reduction or be transferred to a facility capable of providing such treatment.

Various muscle groups insert on or originate from different sites on the elbow. If there is a concomitant elbow fracture and dislocation, the muscle groups can pull the bones or segments of fractured bones in different planes, causing displacement, shortening, and/or angulation. Such deformities will make elbow relocations more difficult.

Radiographs

Standard anteroposterior and lateral views of the elbow should be sufficient to diagnose most elbow dislocations. Remember the principle to radiograph the bone above and below the injured joint (i.e., image the arm and forearm bones if there is an elbow injury). Computed tomography with three-dimensional reconstructions can be helpful in assessing for intraarticular fragments and the congruity of the articular surfaces. Approximately 10% to 20% of elbow dislocations have an associated fracture. Typical fractures associated with elbow dislocations are radial head, olecranon, medial/lateral epicondylar, and coronoid process fractures. Elbow dislocations, specifically dislocation of the ulnohumeral joint, are described based on the position of the olecranon with regard to the humerus (posterior, anterior, lateral, and/or medial). The posterolateral elbow dislocation is the most common. It is rare to have a divergent dislocation, where the radius and ulna are separated from one another and the humerus.

Reduction Techniques

Prompt joint reduction is necessary with elbow dislocations and should not be delayed if there is neurovascular compromise. If orthopedic consultation is not available, examining physicians, if they feel comfortable, can attempt the reduction maneuvers given below or arrange for immediate transfer for orthopedic evaluation. In cases of complicated elbow fracture/dislocation, it is sometimes better to reduce and repair these injuries in the operating room.

Before any elbow reduction, the examiner should provide adequate pain relief with a local joint infiltration with an anesthetic. In the emergency room setting, intravenous or intramuscular sedative agents can be used adjunctively.

There are several elbow reduction techniques described in the literature, with the most common method being the traction-countertraction method. With this method, the patient is placed supine and the elbow slightly extended to 30° to 60°. Gentle longitudinal traction is placed on the wrist and/or forearm along the axis of the ulna while an assistant places countertraction on the upper arm. This helps disengage the dislocated articulation. Simultaneously, manual pressure and bony manipulation are used to correct any displacement of the olecranon seen on radiographs. Medial and lateral displacement of the olecranon should be realigned first with gentle forearm supination and pronation. For posterior dislocations, a posterior-directed force is placed on the distal humerus, while a downward and anterior-directed force is placed on the proximal forearm and olecranon. For anterior dislocations, a posterior-directed force is placed on the distal humerus along with a downward pressure applied to the proximal forearm. If these methods fail, the patient can be placed prone with the elbow hanging off the side of the examining table and the distal humerus resting against the table on a towel. A 5- to 10-pound weight can be hung from the wrist for several minutes to help fatigue the muscles. The steps above can be repeated. A noticeable clunk may be felt when the joint is relocated. If the elbow cannot be relocated, there may be an interposed bony fragment or soft tissue entrapment blocking reduction. These injuries may need further imaging (computed tomography), or the patient may need to be taken to the operating room for reduction.

After reducing the elbow, the examiner should evaluate for any joint instability and perform another thorough neurovascular exam. Joint stability can be tested with gentle elbow flexion/extension, forearm pronation/supination, and gentle varus and valgus stress testing with the elbow at approximately 300° of flexion. Check for any mechanical blocks or redislocations. Indications for surgical repair include any bony or soft tissue entrapment, any large associated fractures, or any instability after reduction.

Postreduction Care

For simple dislocations without any evidence of fracture or instability, patients can be treated with an arm sling for comfort, or a well-padded extension block splint can be used. The elbow is placed at 60° to 90° of elbow flexion with the forearm in neutral position in the splint. The patient should be given anticipatory guidance regarding the signs and symptoms of forearm compartment syndrome. Urgent orthopedic referral is indicated for any elbow that remains unstable, has re-dislocated, or has entrapment of either fractured fragments or soft tissue within the joint. Follow-up evaluation and repeat radiographs should take place at 1 week, and early, simple ROM exercises should be started at that time to prevent elbow stiffness. Prolonged immobilization can adversely affect outcome and time to recovery. Typical recovery period ranges from 3 to 6 months. Long-term complications may include stiffness, recurrent pain, arthritis, myositis ossificans, recurrent instability, ligament damage, contractures, or nerve injury.

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See also Elbow and Forearm Injuries; Elbow and Forearm Injuries, Surgery for; Elbow Sprain

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Elbow Fracture

An *elbow fracture* is an injury to bone (humerus, radius, or ulna) usually caused by a fall on an outstretched hand (FOOSH) resulting in enough impact to break the cortex. Elbow fractures occur commonly in contact sports and constitute 10% of all fractures in children. Other mechanisms of injury include direct trauma or a strong directional force on the elbow. Any athlete who sustains trauma to the upper extremity should have a thorough evaluation of the elbow for the possibility of an elbow fracture or dislocation (see the entry Elbow Dislocations), as well as a thorough examination of the entire upper extremity for any associated injuries.

Anatomy and Clinical Evaluation

The elbow is one of the most complex joints in the body, consisting of three articulations: ulnotrochlear, radiocapitellar, and proximal radioulnar. The elbow is extremely congruent and stable due to the specific pattern in which the bones contact and conform to each other. Due to this configuration, anatomic alignment must be restored to decrease or minimize functional disabilities resulting from the injury. Common complications include decreased range of motion (ROM), structural instability, arthritis, nerve palsies, weakness, and heterotopic ossification.

Physical examination includes inspection for swelling or deformities. The anatomic triangle formed by the radial head, lateral epicondyle, and olecranon can be disrupted or swollen, indicating the presence of a joint effusion and intra-articular pathology. Normal ROM is elbow flexion/extension 0° to 150° and forearm pronation and supination 90° in each direction. A complete neurovascular examination must be performed because associated neurovascular injuries can occur.

It is helpful to categorize and evaluate elbow injuries by compartments. The *posterior compartment* involves the olecranon, triceps, and borders of the ulnar groove; the *medial compartment* contains the medial epicondyle, ulnar aspect of the olecranon, flexor muscle bundle, and ulnar nerve; the *lateral compartment* houses the radial head, lateral epicondyle, extensor muscle bundle, and radial nerve; and the *anterior compartment* includes the biceps, brachial artery, and median nerve. Focal bony tenderness, such as that over the radial head, might uncover subtle fractures.

Radiographs

Standard anteroposterior and lateral views of the elbow should be sufficient to diagnose most elbow fractures. Comparison views are particularly helpful in evaluating the pediatric elbow for fractures due to the presence of six primary ossification centers, which develop between 2 and 14 years of age. Computed tomography may identify intra-articular fragments and assess the congruity of the articular surfaces when internal fixation is being considered.

Certain radiographic signs can suggest the presence of an elbow fracture. The lateral radiograph is helpful to evaluate for a hemarthrosis (bleeding into the joint space) and bony alignment. The anterior fat pad "sail sign" or the presence of a posterior fat pad results from a hemarthrosis and suggests the presence of a fracture or other intra-articular pathology. Extra-articular fractures may not displace these fat pads, whereas joint infections and inflammatory processes may elevate these fat pads and mimic fractures. If the anterior humeral line and the radiocapitellar line do not cross the capitellum appropriately, then a fracture with displacement is suspected.

Radial Head and Neck Fractures

Radial head and neck fractures are the most common elbow fractures in adults. The radial head is palpated distal to the lateral epicondyle and radiocapitellar articulation. Forearm pronation and supination while an examining finger is placed over this region can help expose the radial head, examine its motion, and assess for focal tenderness. A radiocapitellar view is an oblique elbow radiograph with the forearm in neutral position and beam aimed 45° cephalad. This image can define the extent of the fracture (Figure 1).

Fractures that are nondisplaced, nondepressed, and without a mechanical block can be treated

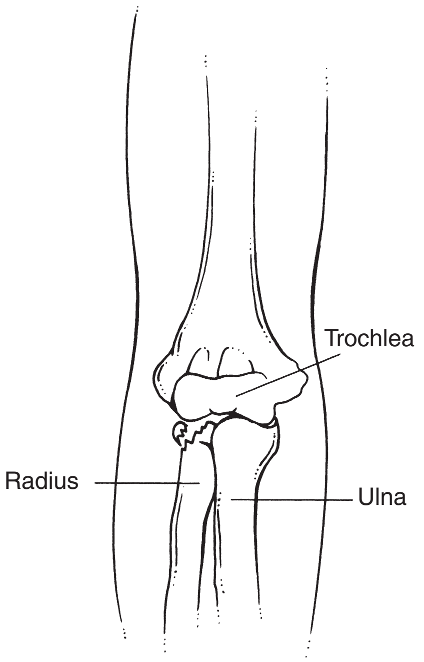

Figure 1 Fracture of the Radial Head of the Humerus

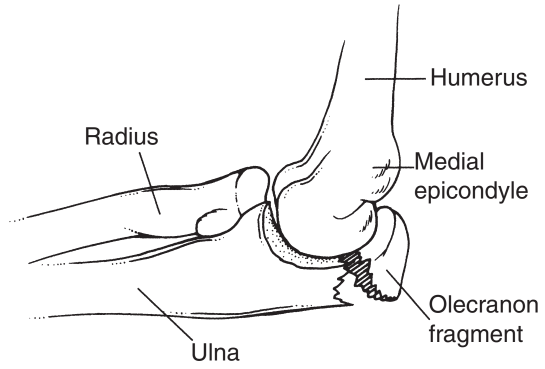

Figure 2 Olecranon Fracture

Note: A fall on the arm or elbow may cause a break across the point of the elbow (olecranon).

acutely with a long-arm posterior splint with the elbow in 90° of flexion and the forearm in neutral position, followed by early ROM exercises. Initial follow-up and repeat radiographs should occur within 1 week. Emergent orthopedic consultation is indicated for fractures with a mechanical block (clicking, catching, or locking), >2 millimeters (mm) of displacement, >10° of angulation, >30% of articular surface involvement, or comminution.

In skeletally immature children, the region is mainly composed of cartilage, so radial head fractures make up a small percentage of pediatric elbow fractures. Fractures that involve the growth plate (Salter-Harris classification) completely can cause a radial head translocation. Fractures with <4 mm of translocation or <30° angulation can be treated conservatively as above, and more displaced fractures can be referred to a pediatric orthopedist.

Olecranon Fractures

Olecranon fractures typically occur from direct trauma to the point of the elbow. Olecranon process and physeal (Salter-Harris classification) fractures are rare in children. The amount of displacement on radiographs is measured with the elbow in both a gently flexed (near 90°) and an extended position, as tolerated. Any comminution, >2 mm of displacement, any changes in displacement on flexed and extended radiographs, and anyone unable to actively extend the elbow (loss of triceps function) should be referred to an orthopedist.

A long-arm posterior splint with the elbow in approximately 60° of flexion can be used initially. The elbow should not be flexed past 90° because the pull of the triceps on the olecranon can cause further displacement (Figure 2). Nondisplaced fractures should have follow-up examination within 1 week.

Distal Humerus Fractures

Fractures in the distal humerus are categorized based on the level of the fracture in relation to the condyles.

Supracondylar/Transcondylar Fractures

Supracondylar fractures are the most common elbow fracture in children and are most common between the ages of 5 and 10 years. *Transcondylar* fractures break through at the level of the condyles and occur more frequently in elderly patients. Both fracture types have similar management plans. Any fractures that are displaced or with >20° angulation should be referred to orthopedics. Experienced providers can manage nondisplaced fractures with a long-arm posterior splint with the elbow in neutral position. Follow-up evaluation and repeat radiographs should take place in 2 to 3 days.

Intercondylar Fractures

Intercondylar fractures occur between the condyles and have intraarticular extension. These are the most common type of elbow fractures in adults. Intercondylar fractures should be referred for evaluation by an orthopedic surgeon.

Condylar Fractures

Condylar fractures occur through the condyles. Lateral condyle fractures are more common than medial. All condylar fractures should be referred to an orthopedic surgeon.

Epicondylar Fractures

The distal humeral epicondyles serve as attachment sites for the forearm flexor (medial epicondyle) and extensor muscle groups (lateral epicondyle). In adults, it is rare to have an isolated epicondylar fracture. In children, medial epicondylar fractures are the third most common elbow fracture, behind supracondylar and lateral condylar fractures. Minimally displaced fractures can be treated nonoperatively with splinting, as described for condylar fractures. Indications for orthopedic referral include >5 mm of displacement, nerve palsy, tissue entrapment, or varus/valgus instability of the elbow.

Fractures of the Coronoid/Capitellum/Trochlea

Isolated fractures of the coronoid process, capitellum, and trochlea are rare. Fractures of these structures typically occur with other injuries, such as an elbow dislocation. They are difficult to detect as the fragments can be small. These injuries should be referred to an orthopedic surgeon.

Follow-Up and Return To Sports

At the initial follow-up, if the fracture is stable on radiographs and there are no signs of instability or neurovascular compromise, a long-arm cast is applied, except for most radial head fractures. Elbow fractures are followed closely, with follow-up visits every 1 to 2 weeks with serial radiographic evaluation.

Immobilization is typically required for 6 weeks. Daily activities and simple exercises can be modified according to patient status. Early ROM exercises can prevent joint stiffness and shorten recovery time. In the initial stages of rehabilitation, obtaining a greater degree of motion is more important than gaining strength. Physical therapy can be prescribed to help regain ROM and strength soon after immobilization is discontinued.

The patient should be aware that some loss of extension can be expected (about 15°), but this should not affect function. It may take up to 3 months to recover full elbow ROM and strength. Vigorous sports activity can be allowed by approximately 2 to 3 months, with clearance for collision sports when almost full strength and ROM are achieved.

Holly J. Benjamin and Brian Tho Hang

See also Elbow and Forearm Injuries; Elbow and Forearm Injuries, Surgery for; Elbow Dislocations

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Elbow Sprain

Elbow sprains are commonly occurring injuries, yet they must be distinguished from other types of elbow injuries, such as fractures, dislocations, osteochondritis dissecans, growth plate injuries, congenital abnormalities, and common neurovascular injuries such as ulnar neuritis. A diagnosis of *elbow sprain* refers to an injury to either the medial or lateral ligament complexes of the elbow. The ligaments play important roles in maintaining elbow joint stability, particularly in the setting of functional movement such as throwing. For example, stresses across the medial elbow joint have been found to reach velocities of greater than 2,300 degrees per second during the acceleration phase of throwing, and valgus torque is reported to have reached 64 Newton meters (N m) in the late cocking phase. The static strength of the ulnar collateral ligament (UCL) measures about 32 N m in elbow flexion; thus, the remainder of medial elbow stability is provided by the bony and other soft tissue structures in the elbow. Elbow ligament injuries often occur in association with or as a result of other injuries, such as elbow dislocations. Medial injuries occur more frequently than lateral ligament injuries. The most common complication of either a medial (ulnar) collateral ligament or a lateral collateral ligament elbow injury is chronic structural or functional instability. This can lead to poor outcomes and a variety of complications, such as decreased range of motion (ROM), arthritis, nerve palsies, weakness, and heterotopic ossification. All athletes with elbow pain must be evaluated promptly for signs of ligamentous injury. The presenting history varies from acute or chronic elbow pain, clicking, catching, or snapping to a spectrum of giving way/subluxation with flexion/pronation in medial injuries or extension/supination with lateral injuries.

Mechanism of Injury

The most common mechanism of injury to the medial elbow involves repetitive valgus overload. The stress to the flexor-pronator muscle-tendon group and/or the UCL results in injury. In skeletally immature athletes, it is more common to experience a medial epicondylar injury, ranging from apophysitis to an acute avulsion fracture, diagnosed by widening or separation of the medial epicondyle on elbow radiographs. The spectrum of UCL injury ranges from minimal fraying to partial ligament tears to complete ligament tears. Lateral elbow injury is part of a spectrum on injury to the lateral elbow soft tissues, either from repetitive varus loading or following a traumatic elbow injury, such as an elbow dislocation.

Anatomy and Clinical Evaluation

The elbow is one of the most complex joints in the body, consisting of three articulations: ulnotrochlear, radiocapitellar, and proximal radioulnar. The elbow is extremely congruent and stable due to the specific pattern in which the bones contact and conform to each other. Stability is maintained at less than 20° and greater than 120° by the bony architecture. Between 20° and 120°, stability is maintained by the soft tissues. Normal ROM of the elbow is approximately 150° of flexion to 0° of extension, 90° of forearm pronation, and 90° of forearm supination. The elbow provides attachment sites for various muscle groups and ligaments. The primary stabilizers of the elbow are the ulnotrochlear articulation and the medial collateral (MCL) and lateral collateral (LCL) ligaments. The radial head and surrounding muscle bundles make up the secondary stabilizers of the elbow. Supination of the ulna results in a posterolateral displacement away from the trochlea in posterolateral rotatory instability (PLRI).

The medial ulnar collateral ligament (MUCL) consists of anterior oblique, transverse oblique, and posterior oblique bundles. The anterior oblique bundle is the most important structure that provides valgus stability to the elbow. It originates on the anteroinferior medial humeral epicondyle and inserts on the medial coronoid. The posterior oblique bundle originates on the posteromedial epicondyle and inserts posterior and proximal to the anterior bundle. The anteromedial joint capsule and the common flexor origin function as additional soft tissue–stabilizing structures to the medial elbow. The lateral ulnar collateral ligament (LUCL) complex consists of four structures: the LUCL itself, the annular ligament, the radial collateral ligament, and the accessory LCL. The posterolateral joint capsule, capsular insertion of the annular ligament, and common extensor origin function as secondary soft tissue restraints to the lateral elbow. Tenderness to palpation of either the MUCL or the LUCL is highly indicative of injury, and various stability-testing maneuvers must be performed to adequately assess elbow joint injuries.

Multiple techniques exist for performing a valgus stress test on the medial elbow. These tests are often positive for reproducing pain as well as demonstrating signs of associated instability. Valgus stress testing at 70° to 90°, the moving valgus stress test, and the milk test are all described techniques. The moving valgus stress test is positive when a valgus stress is applied during flexion/extension and pain is elicited at 70° to 120°. The milk test is positive when pain is elicited by having the patient reach under the affected elbow with the contralateral hand and grasp the ipsilateral thumb to apply a valgus stress. Any perceived laxity should be compared with the contralateral side.

The lateral pivot-shift test is the most sensitive examination technique described for assessing instability of the LUCL. The patient is placed in a supine position with the shoulder in external rotation and the arm overhead. The elbow is first fully extended and supinated. Valgus, supination, and axial compression forces are generated as the elbow is flexed. Rotary subluxation of the ulnohumeral joint may be reproduced at approximately 40° of flexion, with pain and a prominence of the radial head noted. Further flexion actually reduces the joint. Patients often experience significant apprehension during this maneuver. The push-up sign occurs when apprehension, subluxation, or dislocation occurs on terminal elbow extension from a flexed position in a wide-shoulder push-up position. The chair sign occurs when the patient arises from a seated position by pushing on the chair arms with the elbows flexed 90°, the forearms supinated, and arms abducted. This test yields a positive result when apprehension, subluxation, or dislocation occurs.

Imaging Studies

Standard anteroposterior (AP), oblique, and lateral views of the elbow should be sufficient to diagnose most bony abnormalities, such as fractures. The lateral radiograph is helpful to evaluate for a hemarthrosis and bony alignment. Comparison views are particularly helpful in evaluating the pediatric elbow for fractures due to the presence of the six secondary ossification centers. The apophyses slowly close by ossification as the elbow matures and are fully closed by approximately 16 years of age. MUCL injuries are far more common than medial epicondylar fractures once full skeletal maturity is achieved. Valgus stress views may be obtained, but they often fail to demonstrate the gross laxity detectable on physical examination.

Advanced imaging techniques such as computed tomography may identify intraarticular fragments and assess the congruity of the articular surfaces when internal fixation is being considered. Continuous fluoroscopy during the pivot-shift test and stress radiographs may be useful to confirm the diagnosis of recurrent elbow instability. Widening of the ulnohumeral joint or posterior subluxation of the radial head demonstrates PLRI. Musculoskeletal ultrasound techniques are developing and are increasing in popularity as they offer a dynamic imaging modality to assess joint instability during active ROM and valgus stress testing. True sensitivity and specificity of stress testing with any imaging study have not been determined.

Magnetic resonance imaging (MRI) or MR arthrography is the most sensitive and specific imaging study to reveal injury to the MUCL, showing edema within the ligament as well as differentiating partial-thickness from full-thickness tears. MRI is also useful in detecting osteochondritis dessicans, intraarticular cartilaginous loose bodies, and physeal maturity. Increased signal at the medial epiphysis on MRI in the absence of widening or displacement in a skeletally immature elbow indicates chronic medial injury consistent with valgus overload syndrome. MRI has a more limited role in demonstrating PLRI as it is difficult to assess the true extent of LUCL complex injuries; however, edema and structural integrity of the LUCL should be similarly identified as with the MUCL.

Treatment

Nonoperative treatment involves rest from activities that can aggravate both medial and lateral UCL ligament injuries that are not grossly unstable. Frequently, a period of immobilization of 3 to 4 weeks is necessary to prevent recurrent valgus/varus stresses even with activities of daily living. Operative treatment with elbow arthroscopy is a better definitive treatment of choice for athletes, particularly those involved in throwing activities or other overhead sports, and for those patients with gross or persistent instability despite an adequate trial of conservative treatment. Particularly for tears to the MUCL, surgical repair has met with varying degrees of success. Reconstruction remains the preferred intervention for unstable MUCL tears. A prolonged rehabilitation period of 12 to 18 months is necessary to ensure successful return to overhead activities.

Rehabilitation

Rehabilitation of an injured elbow is essential to restore strength and stability whether the injury is treated operatively or nonoperatively. When rehabilitation is initiated, a progressive program of ROM, strength, and multiplanar exercise such as throwing may take weeks to months to complete. A comprehensive core strength training program as well as an evaluation of sport biomechanics, such as pitching technique, is an essential part of any successful rehabilitation program. The consequences of untreated or inadequately treated elbow instability due to ligament or other soft tissue injury include stiffness, osteophyte formation, ulnar neuritis/neuropathy, soft tissue/synovial hypertrophy, or signs of impingement such as pain, locking, crepitus, and/or loss of extension. In conclusion, many elbow sprains, particularly when associated with valgus overload and repetitive microtrauma, are potentially preventable in athletes. It is strongly suspected that an MUCL sprain is a precursor to a complete UCL tear. Therefore, prompt evaluation and early intervention can minimize the risks of permanent injury or long-term sequelae.

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See also Elbow and Forearm Injuries; Elbow and Forearm Injuries, Surgery for; Elbow Fractures

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Electrical Stimulation

Fractures are common sports injuries. In athletes, fractures result in many missed games and practices as well as countless medical visits. Most fractures heal with conservative treatment, which includes rest from sports and immobilization. However, some fractures result in either delayed (slow) healing or nonunion (incomplete healing). Electrical stimulation promotes bone growth and repair of fractures in athletes. Consequently, this may accelerate a fracture's ability to heal. It is used as a last resort to heal delayed and nonunion fractures, before surgery is recommended, and also as an adjunct therapy to surgery itself.

Mechanism of Bone Healing and Electrical Stimulation

Bone is living tissue made up of many different types of cells in an organized structure. Bone is constantly undergoing the process of renewal and repair. When a bone breaks, the body immediately begins the repair process.

Bone heals through a number of phases in a process called *remodeling*. It has a dynamic (constantly changing) environment. Old bone is removed by cells called *osteoclasts*, and new bone is formed by *osteoblasts*. Generally, bones heal better and faster in children than in adults. A solid union (complete healing) of a fracture usually occurs in 3 months. Other factors that affect bone healing include the type and location of the fracture.

Bone healing is based on its position and the amount of stress that is put on it. This is known as *Wolfe's law*. A long bone will return to a shape that is mechanically the most suitable for its function. Examples of long bones include the femur and the tibia in the leg.

Mechanism and History of Electrical Stimulation

Studies suggest that electrical stimulation may activate cellular pathways that promote bone healing. When the correct amount and type of energy are applied to bone, calcification as well as mineralization of the repair are encouraged.

Electrical stimulation has been used for decades to aid healing of fractures that are difficult to heal. In the 1950s, scientists determined that electrical current affects bone healing. Fukada and Yasuda showed that there is a relationship between electricity and the formation of callus. They showed that bone is piezoelectric, meaning that it causes the separation of charge when stressed.

When stress is applied to the bone, the concave (curved in) side has a positive charge, and the convex (curved out) side has a negative charge. This is particularly significant in long bones. When the bone is positively charged, osteoblastic (bone building) activity occurs. When there is a negative charge, osteoclastic (bone absorption) activity occurs. Electrical stimulation changes the electrical potential across the bone to stimulate osteoblastic activity. It therefore replicates the negative potential created at fracture sites by the body's electrical impulses.

Electrical Stimulation and Sports Injuries

Historically, electrical stimulation has been used to heal long-bone fractures. It has also been effective in treating nonunion of carpal navicular fractures. Electrical stimulation has been used after spinal fusions in athletes. Electrical stimulation may also have a role in healing sports-related stress fractures and stress fractures of the foot and the spine. A solid, bony union (complete healing of the fracture) gives the best results. However, some athletes return to sports with a fibrous union (painfree nonunion). It is important to monitor the athlete for recurrent or new symptoms that are problematic.

This treatment modality offers another option to bone grafting, which has been used previously. In addition, it avoids the risks of an open operative procedure. These include bleeding, infection, risk, discomfort, and the high costs of repair.

Types of Electrical Stimulation

There are three types of electrical stimulation: (1) direct current (DC), (2) capacitive coupling (CC), and (3) pulsed electromagnetic field therapy (PEMF). DC is the most invasive of these since it involves surgical intervention. In this form of therapy, the electrical stimulation device is implanted in the patient near the fracture site. DC eliminates the need for patient compliance, which may be especially difficult in athletes.

CC and PEMF are noninvasive electrical bone growth stimulations that involve a portable unit. Success of these treatment modalities partly depends on athlete compliance. CC is delivered from a battery pack to two wires. The wires are attached to skin electrodes. The electrodes (skin pads) are positioned on one side of the fracture or fusion site. The treatment is generally given for 24 hours a day until healing occurs.

PEMF is applied by an external coil for several hours per day. Treatment coils (placed in a brace or on the skin) are applied directly onto the skin. In PEMF, a treatment coil is positioned directly on the fracture site. A treatment unit is programmed to deliver the therapy. This is based on the requirements of the athlete's specific fracture. A small electrical current, produced by the treatment unit, travels to the treatment coil. A pulsating electromagnetic field is produced around the fracture. The electromagnetic field produces a small electrical current similar to the initial current. This stimulates the fracture to heal.

Ultrasound

Ultrasound is another form of therapy to treat fractures. It is used to heal new fractures, as well as for part healing of older fractures. Animal and clinical studies report good to excellent results using ultrasound to heal fractures. However, it is important to consider that treatment outcome in athletes depends on the site of the nonunion, how much time has passed from the time the fracture occurred, and how stable the nonunion is.

Ultrasound stimulates piezoelectric forces, which promote fracture healing in athletes. The exact mechanism by which ultrasound works is not known. It may be accomplished by mimicking signals sent by the body that promote osteoblastic activity and, therefore, fracture healing. Another proposed mechanism is that the bone absorbs sound waves from the ultrasound. This causes chemicals necessary for bone healing, such as calcium, to move across the bone's surface and promote fracture healing.

Application time for ultrasound treatment is minimal; it generally takes 30 minutes. The ultrasound is applied on the skin through a window in the immobilization device if the athlete is casted. This restricts the athlete's motion. The ultrasound device is connected to a power source on a wall.

A number of different factors affect bone healing, and electrical stimulation and ultrasound offer additional options for athletes with fractures that are difficult to heal.

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See also Carpal Fractures; Fractures

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Electromyography

Electromyography (EMG) is the study of muscles and nerves. The test includes two components: (1) nerve conduction studies (NCS) and (2) the electromyogram (EMG). While technically EMG refers to the electromyogram part of testing, it is used colloquially to refer to the entire electrodiagnostic testing process.

The ability to record electrical activity during active muscle contraction was first discovered in 1849, but it was not recorded until 1890. In the 1920s, that signal was displayed on an oscilloscope, and EMG testing, albeit rudimentary, was first developed. As the technology for electrical circuits evolved, so did the technology to observe, record, and edit electrical activity generated from muscle. Today's machines are quite sensitive to the minute electrical changes seen in active muscle membranes.

Although EMG testing can provide a wealth of objective information, it is best used as a complement to history and physical examination rather than as a substitute for it. Testing can help confirm a diagnosis, provide a diagnosis, assess chronicity, judge severity, localize a lesion, and predict recovery.

Athletes may suffer from a multitude of different injuries, and EMG testing can help characterize and diagnose some of these. Nerve injury typically presents with weakness, numbness and tingling (paresthesias), or a painful sensation (dysesthesias), and it can be evaluated by EMG testing. Even with symptoms of sprain or strain, an EMG can be useful to rule out any other underlying problem, particularly if the symptoms continue despite appropriate treatment. While this list is not comprehensive, EMG testing can be helpful for specific injuries such as carpal tunnel syndrome, "pinched nerve" (radiculopathy), ulnar neuropathy (at both the wrist and the elbow), and "stingers."

Nerve Conduction Studies

NCS allow for noninvasive evaluation of the characteristics of peripheral nerves. Some of the characteristics evaluated include onset of response (latency), amount of response (amplitude), and speed of response (velocity).

Recording electrodes are placed over the area of interest, and stimulation is given at a predetermined distance. Data collected include latency, amplitude, and velocity. These data can then be compared with control values ("normal" values). Generalized controls are published in a variety of texts, but each EMG lab will ideally establish its own controls based on its equipment and testing methods. The above characteristics can be affected by temperature, age, gender, and height, all of which must be taken into account when grading the data.

Testing can be further divided into the study of sensory and motor nerves. There are multiple methods and sites to test the peripheral nerves. This helps eliminate false-negative or -positive testing and ensure accuracy of results. Many states allow physicians as well as qualified (and in some cases certified) nonphysicians, such as physical therapists or chiropractors, to perform nerve conduction testing.

The electrical stimulation lasts less than 1 millisecond and is typically felt as an "electric shock." It is generally not regarded as painful but rather as an unpleasant stimulation.

Needle Examination

EMG, or needle testing, quantifies the electrical potential of muscles at rest and muscles in action. Muscles at rest should be electrically silent and when stimulated can be studied to determine the type of pathology. Muscle is also tested with a slight and then full contraction for further characterization. The contraction produces a motor unit action potential (MUAP). This unit of muscle activity can be analyzed for its speed of firing, size of contraction, and duration of firing. These data can help determine whether pathology is originating from the nerve or muscle. The size of the MUAP can help characterize the onset of findings, grossly measured as newer or older than 6 months.

The needle examination is administered by physicians specialized in neuromuscular testing. Testing is performed with a sterile disposable needle and requires an intimate knowledge of anatomy. The needles are not hollow (except for specialized needles used to test and inject medication), so they are not as painful as a hollow bore needle. Despite that difference, needle testing is still regarded as unpleasant to painful.

Electrodiagnostic results are oftentimes dependent. Patterns suggesting acute injuries can be present within days of injury, but for ideal assessment, testing should be done at 3 weeks or more from the onset of symptoms. After nerve injury, there is a process of degradation of the nerve (Wallerian degeneration). Testing before that process has taken place (generally 3 weeks) may result in false-negative test results. Testing and results also change with time. Nerve degeneration and nerve healing will yield different results at follow-up testing.

Electrodiagnostic studies are not standardized. Investigations are frequently modified by the practitioner to answer the diagnostic question. Subsequently, testing can be shortened or lengthened depending on the findings and the need for further investigation.

The Electrodiagnostic Consultation

EMG testing should be used as a complement to a thorough history of symptoms and physical examination findings. While an EMG report contains raw data, it is more than simply that. It also contains interpretation of the data that can help make a diagnosis; confirm a diagnosis; and assess location, age, and severity of injury, as well as predict recovery. Prediction of recovery depends on the type of injury and the time of testing (from the onset of injury) and, subsequently, may be best done with repeat testing. Injuries to nerves, injuries with underlying mechanical problems, or injuries slow to progress are often seen in athletes. EMG testing can be helpful to diagnose, grade, and predict recovery in these cases.

It is also important to stress that despite the presence of pain, loss of function, or any other symptom, EMG testing is not always positive. As EMG testing is used specifically for nerve injury or muscle pathology, testing outside those parameters will yield a "normal" test, despite symptoms. Negative EMG testing does not imply lack of symptoms. Rather, it implies the lack of pathologic nerve or muscle injury.

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Electrotherapy

Electrotherapy is a therapeutic modality that uses electrical currents to improve a wide variety of musculoskeletal conditions. Physical therapists traditionally use these modalities as a component of a comprehensive treatment program to improve impairments and functional limitations that may be caused by an injury. Within the body, there are naturally occurring electrical impulses that travel down the nerve to stimulate a muscle to work. This is a normal physiological mechanism.

Electrotherapy modalities have the following in common: (a) a source of electrical current (battery, outlet), (b) lead wires to conduct the current, and (c) electrodes, coated with a conductive medium, that are placed on the skin to transmit the current into the body.

Electrotherapeutic Modalities

Iontophoresis

Iontophoresis is the introduction of charged ions across the skin using low-voltage direct current. The active electrode is placed over the area to be treated, and a second dispersive electrode, which completes the electrical circuit, is placed on the body away from the first electrode. The active electrode is the one with the same polarity as the drug ions, which causes the drug to be driven across the skin. The drug used most often is dexamethasone sodium phosphate, which can help decrease inflammation often caused by tendinitis or bursitis. Acetic acid can also be used to eliminate calcium deposits from a joint.

Transcutaneous Electrical Nerve Stimulation

Transcutaneous electrical nerve stimulation (TENS) is a form of electrical stimulation that can help with pain control. Pain relief can be achieved through two mechanisms. The first is the gate control theory. This proposes that electrical stimulation inhibits transmission of painful stimuli from the spinal cord to the brain. This is called high-rate or conventional TENS, and it uses high-frequency, low-intensity pulses. No muscle contraction occurs. The second theory is that electrical stimulation can stimulate the release of the body's own natural endorphins and enkephalins. This is often called low-rate or acupuncture-type TENS, and it uses low-frequency, high-intensity pulses. Mild muscle contraction occurs. Currents are superficial with TENS due to high skin resistance to the pulse frequencies. TENS may be used to help control acute pain (postoperative) or pain in more chronic conditions, such as low back pain and complex region pain syndrome (CRPS).

Interferential Current

Interferential current (IFC) is similar to TENS, but it uses two different channels with medium frequencies. The currents intersect and interfere with each other, producing a current that is said to penetrate the skin more deeply and more comfortably, thus providing pain relief to deeper tissues. It is claimed that IFC may be effective for pain control in acute, subacute, and chronic pain conditions, but TENS is often as effective.

Electrical Stimulation With Direct Current

Electrical stimulation with direct current is used when the nerve has been affected by injury and the patient is no longer able to produce a voluntary muscle contraction (denervated muscle). The type of pulse it generates produces a twitch response in the muscle. Traditionally, direct current was used to produce muscle activity with the intention that it would prevent muscle atrophy. Recent studies have not supported this outcome, except in some cases of chronic facial nerve palsy (Bell palsy).

Neuromuscular Electrical Stimulation

Neuromuscular electrical stimulation (NMES) is used when the nerve is intact. This type of current may be used to produce a strong muscle contraction similar to what is done voluntarily. This modality is most commonly used to increase muscle strength. To optimize this effect, the electrical stimulation should be as high as the athlete can tolerate. The athlete should attempt to perform a voluntary contraction in conjunction with the electrically generated contraction. NMES is also used to decrease spasticity, to decrease muscle spasm, and to enhance local circulation.

Functional Electrical Stimulation

Functional electrical stimulation (FES) is a form of NMES that is applied during functional activities. It has been used recently in the treatment of spinal cord injuries, hemiplegia due to stroke, and children with cerebral palsy. The electrodes are placed on the motor points of the muscle(s) needed for the functional activity, for example, walking and/or relearning hand function after a stroke.

High-Voltage Pulsed Current

High-voltage pulsed current (HVPC) is a form of electrical stimulation that can help decrease swelling after an acute injury, such as ankle sprain, thus helping with pain control. This kind of electrical stimulation has also been shown to be effective in wound healing, especially with decubitus ulcers.

Contraindications

Standard contraindications on the use of electrical stimulation include the presence of a cardiac pacemaker, active bleeding/infection, malignancy in the area being treated, and stimulation directly over a metal implant. Athletes should have intact sensation in the affected area and should have an understanding of the intervention being used.

Penelope Sullivan, Joan Widell, and Michelina Cassella

See also Carpal Tunnel Syndrome; Cervical Nerve Stretch Syndrome

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Emergency Medicine and Sports

Many recreational activities and sports, particularly those in which children participate, do not have medical coverage on site. Consequently, many injuries that occur in sports are seen by doctors in emergency rooms for acute care. The Centers for Disease Control and Prevention (CDC) in the United States reports more than 30 million emergency room visits annually for injuries. The focus of emergency room care is immediate stabilization and accurate diagnosis. Emergency doctors must triage, assess, and provide initial care for athletes with injuries. Ongoing management and follow-up are done elsewhere, outside the emergency room.

Injuries sustained by athletes range from very minor (bruises, contusions) to more severe (spleen lacerations, multiple fractures). Most injuries that occur as a result of sports are not life threatening, but many musculoskeletal injuries (ligament or tendon tears, cartilage injuries, broken bones) require expert care to ensure appropriate rehabilitation in order to allow athletes to return to sports safely. The role of the emergency doctor is to make the appropriate diagnosis and then to ensure the appropriate follow-up for athletes.

When to Go to the Emergency Department for a Sports Injury

Severe sport injuries are not common, particularly among adult recreational athletes. However, some injuries can be life threatening, and immediate medical attention in an emergency room should be sought. Potentially serious injuries may be indicated by the following characteristics:

- Deformity of a bone or a joint
- Localized tenderness or pain
- Decreased level of consciousness/loss of consciousness
- Drowsiness, confusion, and disorientation
- Persistent vomiting
- Leakage of clear fluid from the ears or nose
- Different-sized pupils/pupils that don't react to light
- Change in vision
- Seizure
- Neck pain following an impact
- Significant bleeding from a wound
- Severe pain
- Difficulty in breathing after a blow to the chest, head, or neck
- Inability to bear weight
- Pain that gets worse with activity
- Significant swelling or bruising

The presence of any of these symptoms should prompt immediate medical attention.

Diagnosis of Injury

When an athlete presents to the emergency room with an injury, the emergency doctor must make an accurate diagnosis to start appropriate initial management and to be able to give appropriate advice to the athlete. To do that, the doctor follows a standard approach to trauma, which includes a primary survey, resuscitation as necessary, secondary survey, and definitive care. The doctor will assess the severity of the injury by taking a thorough history, performing a thorough physical examination, and carrying out necessary diagnostic tests.

Primary Survey

The primary assessment includes measurement of vital signs and a rapid assessment of the essential functions of all organs. The goal of the primary survey is to identify any life-threatening conditions and to start any necessary resuscitation measures as soon as possible. The primary survey includes an assessment of the *A*irway/cervical spine, *B*reathing, *C*irculation, *D*isability, and *E*xposure/environment (ABCDE). This is a stepwise assessment, and each step must be completed before moving on to the next step. Any problems with the airway, breathing, or circulation in an injured athlete must be dealt with immediately by the emergency doctor before moving on to assess the extent of other injuries. The ABCDE primary survey is described in detail in the entry Fieldside Assessment and Triage.

The majority of sports injuries do not require an extensive primary survey, and assessment proceeds quickly to the secondary survey.

Secondary Survey

The secondary survey involves a thorough, systematic head-to-toe exam to detect any non–life-threatening injuries, with detailed examination of the injured body part to determine the nature and extent of injury. It includes taking a thorough history and possibly investigations to help make a diagnosis.

History

When assessing a patient with a sport-related injury, the emergency doctor must obtain some important details from the athlete and/or witnesses about the injury to help make an accurate diagnosis. The doctor will ask questions, including what sport/activity the patient was playing, the mechanism of injury, and what immediate treatment/interventions occurred at the time of injury. Other questions the doctor may ask include where the injury hurts; whether there was any popping, cracking, or snapping at the time of injury; and whether there had been previous injuries to the same body part and, if so, what treatment had been given.

Physical Examination

The doctor will perform an appropriate physical examination, depending on the location and nature of the injury. For musculoskeletal injuries, a complete musculoskeletal exam of the athlete must be performed by the doctor to help make the diagnosis. The doctor will look for signs that may indicate an orthopedic injury, such as swelling, loss of function, redness or discoloration, bruising, deformity or abnormal appearance, tenderness, or abnormal range of motion. Abnormal findings on physical examination may prompt the doctor to organize investigations.

Investigations

If there is a concern that an acute bony injury has occurred, such as when there is significant swelling or deformity, X-rays can be obtained in the emergency room. Soft tissue injuries and some nonacute bony injuries (such as stress fractures) may require further imaging, such as ultrasound, computed tomography (CT) scan, magnetic resonance imaging (MRI), or bone scan. These investigations are usually organized for a later date in the outpatient department.

Range of Injury and Initial Triage

Athletic injuries can be relatively trivial or more serious. Classification of injury can help with the diagnostic process. Categories of injury include

the *extent* of injury—local or multiple;

the *nature* of injury—blunt or penetrating trauma; and

the *severity* of injury—mild, moderate, or severe.

The first diagnostic task for an emergency doctor is to determine if the injury is localized or multiple. Local injury involves only one anatomic region of the body (extremities, head, abdomen), whereas multiple injury involves two or more anatomic areas of the body (head and abdomen, neck and extremities). The distinction between local and multiple trauma may be difficult to figure out initially for a variety of reasons. For instance, some injuries may initially be occult and may take time to manifest (spleen laceration). In addition, an athlete who is unconscious or has an altered level of consciousness may be unable to verbalize the areas of injury. Furthermore, some athletes may hide symptoms of injury because they do not want to be prevented from participating in their sport. Therefore, determination of injury as local or multiple is a dynamic process and may change over time as new evidence becomes available.

After the extent of injury has been determined, the emergency doctor focuses on the anatomical region of injury and ascertains the nature of the injury (blunt vs. penetrating). The vast majority of injuries result from blunt trauma. It is important to distinguish between blunt and penetrating injuries because this will guide the evaluation in the emergency room based on expected internal injuries.

Finally, the severity of injury must be determined. Severity of injury, ranging from mild to severe, determines the extent of investigation and intervention required, as well as the disposition of the patient. Most athletes with mild and moderate injuries will have minimal investigation and intervention and will be discharged from the emergency room with outpatient follow-up. Severe injuries require more investigation and intervention, and most patients will be admitted to hospital.

Types of Injury

Details of diagnosis and management of specific injuries are covered in other entries in this encyclopedia. Table 1 gives the general principles of investigations and emergency room management for general categories of injuries that doctors may see and treat in the emergency room.

Table 1 Emergency Room Management of Injuries

Injury	*Investigations*	*Initial Management*
Sprains/strains	Usually none X-rays if possibility of fracture	PRICE[a] Immobilization as necessary
Lacerations	Usually none	Suturing/steristrips/dermabond as required
Joint dislocations	X-rays pre- and postreduction	Reduction under sedation Appropriate immobilization
Fractures	X-rays Rarely CT	Appropriate casting/splinting
Internal bleeding/organ injury	Ultrasound, CT as necessary	Fluid resuscitation as necessary Surgical consultation Surgery may be required
Head injury	CT scan if concerning features (i.e., vomiting, decreased level of consciousness, focal neurological abnormalities, seizure)	Observation Neurosurgical consultation if significant findings on CT
Eye injuries	Slit lamp exam	Possibly ophthalmology consultation
Dental injuries	Possibly panoramic dental X-rays after dental consultation	Dental consultation

Note: a. PRICE = *p*rotection, *r*est, *i*ce, *c*ompression, and *e*levation.

Management/Discharge Instructions

For athletes with minor or moderate injuries who are sent home from the emergency room, the emergency doctor will provide information about the diagnosis and what to do to make the injury better. Most acute musculoskeletal injuries should be treated with *p*rotection, *r*est, *i*ce, *c*ompression, and *e*levation (PRICE) in the first 24 to 72 hours following injury.

> *P*rotection: This consists of appropriate bracing and immobilization.
>
> *R*est/relative rest: When an injury occurs, sports and exercise should be stopped immediately to avoid worsening the injury. In the first 24 to 72 hours, all sports activity should be avoided. After this acute period, relative rest means avoiding activities that may exacerbate the injury.
>
> *I*ce: Ice packs help decrease inflammation and pain.
>
> *C*ompression: Tensor bandages may help decrease swelling in soft tissue injuries.
>
> *E*levation: Raising the injured body part above the heart level helps decrease inflammation.

PRICE should be started as soon as possible following an injury to help minimize and control inflammation and swelling and, therefore, help decrease recovery time. Time off from sports can be reduced by 50% to 70% if PRICE is started within the first 24 hours of injury.

In addition to recommending PRICE, the emergency doctor may advise the athlete to take anti-inflammatories, such as ibuprofen, to help decrease the pain and swelling. The doctor may prescribe nonsteroidal anti-inflammatories (NSAIDs), such as Naprosyn or Toradol, for more serious injuries.

Emergency room doctors should also make sure that athletes with injuries are seen by an appropriate specialist as soon as possible after discharge from the emergency room. For athletes with broken bones, follow-up should be arranged with an orthopedic surgeon in a fracture clinic. For other injuries, follow-up should be arranged with a doctor who is knowledgeable about sports injuries. For some soft tissue injuries, such as ankle sprains and shoulder tendinitis, the emergency room doctor may also advise the athlete to start physiotherapy to help heal the injury.

Return to Sports

One of the most common questions an athlete with an injury will ask is "When can I return to my sport?" Most of the time, the emergency room doctor will not be able to give a definite answer to that question. It is difficult for emergency room doctors to guide athletes with regard to return to play at the time of initial assessment in the emergency room because a number of factors will affect the timing of return to play. These factors include the severity of the injury, the extent of the injury that may require further imaging outside the emergency room, and response to therapy. It is therefore appropriate that patients be sent for follow-up to a doctor knowledgeable in sports injuries, who can assess the patient's recovery process and help guide the patient's return to sports once the athlete has completed a rehabilitation program designed for his or her specific injury.

Laura Purcell

See also Catastrophic Injuries; Fieldside Assessment and Triage; Head Injuries; PRICE/MICE

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EPICONDYLITIS

Epicondylitis is an overuse injury involving the muscles and tendons that originate on the epicondylar region of the distal humerus. It is fairly common, with lateral epicondylitis ("tennis elbow") and medial epicondylitis ("golfer's elbow") constituting the majority of elbow pain seen in sports medicine clinics. In this entry, we will discuss the anatomy of the elbow as well as the pathology, evaluation, and treatment options for lateral and medial epicondylitis.

Lateral Epicondylitis

Henry J. Morris first described "lawn tennis elbow," now referred to as *lateral epicondylitis*, in 1882 (Figure 1). The annual incidence of lateral epicondylitis is approximately 1% to 3% of the general population, with the majority of patients being 35 to 40 years old or older. Men and women are affected equally. Lateral epicondylitis typically occurs in racquet and throwing sports but can result from work-related injury as well. The etiology is believed to be overuse and repetitive microtrauma from eccentric contractions of the extensor muscles. The injury occurs between the extensor carpi radialis brevis and the periosteum of the lateral epicondyle. A microscopic invasion of immature fibroblast and nonfunctional vascular buds leads to an "angiofibroblastic tendinosis," first described by Nirschl in 1979. Scarring and calcifications develop within the degenerated tendon, with little to no inflammatory cells present; the term *epicondylitis* is a misnomer, as "itis" implies the major cause to be an inflammatory process, and anatomical studies do not support this. Studies have shown that this area is extremely hypovascular—that is, it does not receive a generous blood supply—thus limiting its potential to heal.

For proper evaluation and accurate diagnosis, the examiner must have a good understanding of elbow anatomy. The elbow is a hinge joint that can flex, extend, and rotate. The medial trochlea of the distal humerus articulates with the ulna, allowing for flexion and extension. The lateral capitellum of the distal humerus articulates with the radial head. The radiocapitellar and radioulnar articulations allow for rotation of the elbow joint. Valgus stability is provided by the medial collateral ligament complex, comprising the anterior, posterior, and transverse bundles, with the anterior bundle being the primary stabilizer. Rotational and varus stability are provided by the lateral collateral ligament complex, comprising the radial collateral ligament and annular ligament. Elbow flexion is facilitated by the biceps brachii, brachioradialis, and brachialis muscles. The triceps and anconeus allow for elbow extension. The supinator and biceps brachii are the major supinators, while the pronator quadratus, pronator teres, and flexor carpi radialis muscles are the major pronators. The median, ulnar, and radial nerves all traverse the elbow joint, providing sensory and motor innervation. The brachial, radial, and ulnar arteries are the major vessels of the elbow.

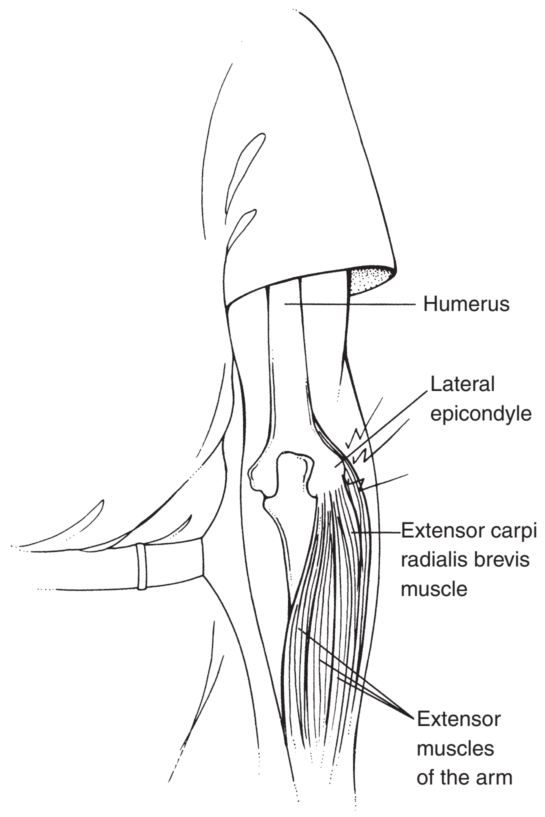

Figure 1 Tennis Elbow (Lateral Humeral Epicondylitis)

Patients with lateral epicondylitis often complain of weak grip and pain along the extensor surface of the forearm. Physical exam shows tenderness to palpation along the lateral epicondyle and extensor carpi radialis brevis. Pain is reproducible with resisted wrist extension, resisted supination, and resisted long finger extension.

The majority of cases are diagnosed clinically, but imaging can help if the presentation is less clear. Plain radiographs (X-ray films) are usually normal but may show a calcification around the epicondyle in 20% of patients. Ultrasound is a noninvasive modality increasingly used both for diagnosis and to guide treatment of epicondylitis. Calcifications, tears, or a thickened, degenerative tendon may be seen, and selective injections and/or tendon fenestration may be done under ultrasound guidance. Magnetic resonance imaging (MRI) is the most sensitive imaging technique, but its utility is usually limited to preoperative imaging. Images may reveal tendon thickening, edema, microtears, and fibrovascular proliferation.

Nonoperative management is the mainstay of treatment for epicondylitis. Treatment may start with rest, ice, activity modification, and "watchful waiting," or it may include medications, bracing, injections, home exercises, physical therapy, or other modalities. Topical nonsteroidal anti-inflammatory drugs (NSAIDs) may be beneficial for pain control; however, there has been no conclusive evidence that oral NSAIDs have the same benefit. Topical medications such as nitric oxide and nitroglycerin have been shown to reduce pain and tenderness; however, more studies are required.

Wrist splints and proximal forearm bands are two of the most common orthoses used for treatment of lateral epicondylitis. The wrist splint decreases wrist extension, thereby relieving the tension on the tendons. The forearm band decreases the full contractile force on the extensor origin. There has been no evidence that one is more effective than the other or that bracing is more effective than other treatment modalities. Various physical therapy modalities have been studied as adjuvant therapies. Strengthening and stretching have been shown to reduce pain in the acute phase. Manipulation and deep friction massage may aid in breaking up adhesions; however, long-term improvement has not been shown to occur. Ultrasound and iontophoresis may reduce pain and increase functionality.

Extracorporeal shock wave therapy (ESWT) has not consistently been shown to improve symptoms. It can also result in pain, redness, swelling, or hematoma. Cortisone injections into the region of the epicondyle have been shown to have high success rates at short-term follow-up; however, studies have shown that there is no long-term benefit and there may be an increased risk of recurrence. Autologous blood injection is believed to stimulate bone and tendon healing, but more studies are needed. Botulinum toxin injection has shown significant reduction in pain in one study but can result in finger paresis and weakness of finger extension. Dextrose injections or prolotherapy may improve pain. Acupuncture may also provide some short-term relief. Ultrasound-guided percutaneous tenotomy, which involves fenestration of the degenerated tendon, has been shown to improve symptoms and functioning level in patients with chronic epicondylitis. All these treatment options are viable options for those with refractory symptoms, prior to considering surgery.

Surgical intervention is reserved for patients with chronic epicondylitis who have failed conservative treatment after 6 months to 1 year. Open surgery includes release or lengthening of the extensor carpi radialis brevis tendon, excision of the diseased tendon, anconeus transfer, denervation, or release of the posterior interosseous nerve. Arthroscopic repair involves release of the tendon or excising of the degenerative fringe. This has been shown to have outcomes comparable with those of open surgery.

Medial Epicondylitis

Medial epicondylitis, commonly known as "golfer's elbow," is an overuse injury at the flexor-pronator tendon origin on the medial epicondyle (Figure 2). Medial epicondylitis is much less common than lateral epicondylitis, making up approximately 10% to 20% of epicondylitis diagnoses. Similar to lateral epicondylitis, it commonly occurs in people ages 30 to 40, and men and women are equally affected. It often occurs in the dominant arm. Excessive valgus stress, rapid wrist flexion, and forearm pronation lead to degenerative changes, as in lateral epicondylitis. Pronator teres and flexor carpi radialis muscles are most commonly affected. Golfers are commonly affected due to an improper swinging technique.

Medial epicondylitis presents with an insidious medial elbow pain, worsened with activity. Physical examination reveals tenderness to palpation at the medial epicondyle, pronator teres, and flexor carpi radialis. Pain is worsened with resisted wrist flexion and forearm pronation. Throwers may also have a flexion contracture or decreased range of motion. In overhead athletes, it is important to rule out medial collateral

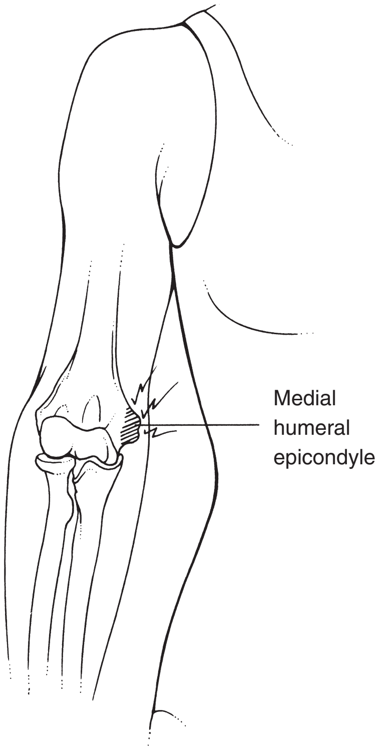

Figure 2 Medial Humeral Epicondylitis, or "Golfer's Elbow"

ligament damage and primary ulnar neuropathy. Medial collateral ligament damage can be determined by a valgus stress test or the milking test, which is performed by pulling the thumb while the elbow is flexed and forearm supinated. The Tinel sign at the cubital tunnel is usually negative in epicondylitis. If positive, it may suggest an ulnar neuropathy. The differential diagnosis of medial elbow pain also includes ulnar collateral ligament (UCL) sprain, flexor-pronator mass injury, and ulnar nerve entrapment.

Plain radiographs may show some calcifications or bony abnormalities. In younger throwing athletes, it is important to rule out an avulsion or medial apophysitis, indicative of "Little League elbow." If the diagnosis remains unclear after a thorough history and physical examination, ultrasound and MRI are other imaging options. The general approach to treatment for medial epicondylitis is similar to that for lateral epicondylitis, with therapy and bracing being first line; however, injections are used with much less frequency due to concern for damage to the UCL or ulnar nerve. Surgery is reserved for refractory cases.

Conclusion

Epicondylitis is a common cause of elbow pain in athletes with repetitive arm movements, especially throwers, golfers, and tennis players. A good understanding of the anatomy and pathophysiology is important to make the correct diagnosis. Most cases of epicondylitis respond to nonoperative therapies; however, full recovery may require more than a year of treatment. Important factors that lead to epicondylitis should be corrected as part of the treatment regimen. For tennis, these include proper strokes, appropriate grip size, lighter frames, and a less tightly strung racquet. In golfers, proper club weight, length, grip, and swing biomechanics can improve outcome. If pain persists or delays return to sport, surgical intervention may be warranted.

Rahul Kapur and Sasha Steinlight

See also Golf, Injuries in; Tennis Elbow

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Epidemiology of Sports Injuries

Epidemiology is the study of the distribution and determinants of varying rates of diseases, injuries, or other health states in human populations for the purpose of identifying and implementing measures to prevent their development and spread. The initial development of the theory and methods of epidemiology focused on applications to infectious and communicable diseases. However, in his classic article "The Epidemiology of Accidents," John Gordon (1949) recognized that injuries conformed to certain biological laws as do infectious diseases and, therefore, could be studied by the application of basic epidemiologic principles. Application of epidemiologic concepts and methods to the characterization and prevention of accidental injury followed. By the early 1960s, epidemiologic techniques were also being applied to sports injury problems. As illustrated in Figure 1, the volume of sports injury research has more than doubled every 10 years since that period of time.

The most well-known and universally accepted model of the epidemiologic approach to sports injury prevention was first proposed by Willem van Mechelen and his colleagues. As illustrated in Figure 2, the injury problem must first be identified and described in terms of the incidence and severity of sports injuries. Then the factors and mechanisms that play a part in the occurrence of sports injuries have to be identified. The third step is to introduce measures that are likely to reduce the future risk and/or severity of sports injuries. Finally, the effect of the measures must be evaluated by repeating the first step.

The epidemiologist in sports medicine is concerned with quantifying injury occurrence (*how much*) with respect to *who* is affected by the injury, *where* and *when* injuries occur, and *what* is their outcome (Step 1), for the purpose of explaining *why* and *how* injuries occur (Step 2) and identifying strategies to control and prevent them (Steps 3 and 4). The study of the distribution of varying rates of injuries (i.e., who, where, when, what) is referred to as descriptive epidemiology. The study of the determinants of an exhibited distribution of varying rates of injuries (i.e., why and how) and the identification and implementation of preventive strategies is referred to as analytical epidemiology.

Descriptive Epidemiology

Descriptive epidemiology is by far the most common type of epidemiologic research that has been published in the sports injury literature. Yet to date, not all sports are sufficiently represented in this literature. For example, sports such as competitive swimming, cycling, and figure skating attract large numbers of participants, yet there are few published epidemiologic studies of injury in these sports. There are also few published studies representing a variety of other Olympic sports, including archery, canoeing/kayaking, shooting, and table tennis (summer sports), and

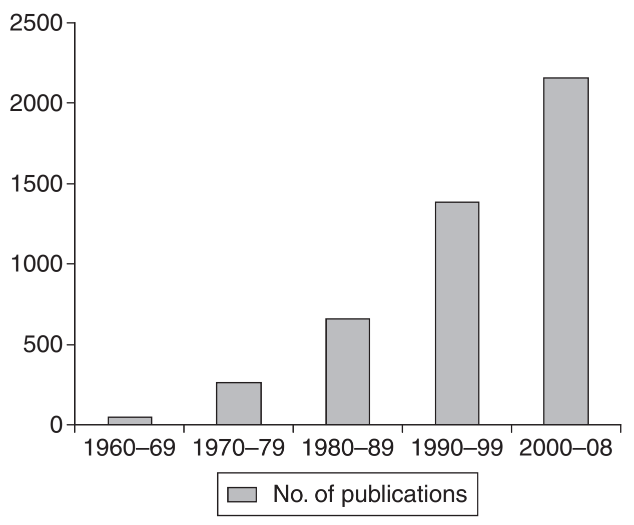

Figure 1 PubMed Publications on "Sports" and "Injury" Epidemiology, 1960–2008

Source: Dennis Caine.

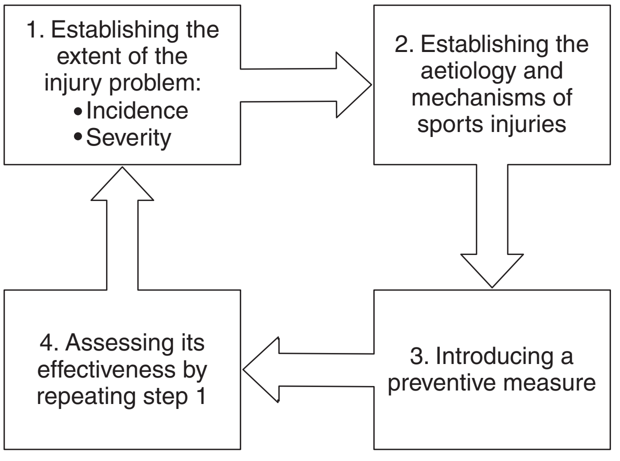

Figure 2 Four-Step Sequence of Injury Prevention Research

Source: Reproduced with permission from van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries: a review of the concepts. *Sports Med.* 1992;14(2):82–99.

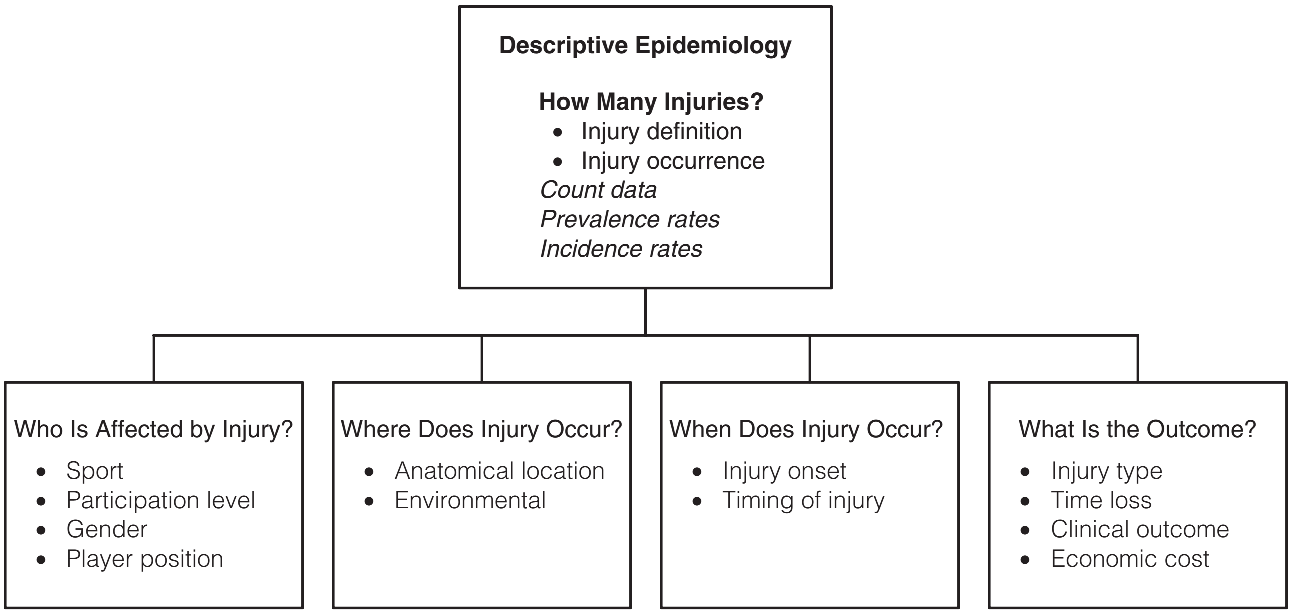

Figure 3 Descriptive Epidemiology of Sports Injuries

Source: Reproduced with permission from Caine D, Caine C, and Maffulli N. Incidence and distribution of pediatric sport-related injures. *Clin J Sport Med.* 2006;16(6):500–513.

biathlon, bobsleigh, skiing (cross-country, free style, Nordic combined, and jumping), curling, and luge (winter sports). Figure 3 is a diagram illustrating the important aspects of the descriptive epidemiology of sports-related injuries. These components are discussed below with the purpose of highlighting their various contributions to understanding the distribution of sports injuries.

How Many Injuries?

In descriptive epidemiology, the researcher attempts to quantify the occurrence of injury. The most basic measure of injury occurrence is a simple count of injured persons or fatalities. For example, in the 25th Annual Report of the National Center for Catastrophic Sports Injury Research (NCCSI), we learn that there have been 25 heatstroke deaths in football during the past 10 years, an unacceptable number given that heatstroke deaths are preventable with the proper precautions.

To investigate the rate and distribution of injuries, it is necessary to know the size of the source population from which the injured individuals were derived, or the population at risk. The two most commonly reported rates in the sports injury literature are *incidence* and *prevalence.* Prevalence rates pertain to the total number of cases, new or old, that exist in a population at risk at a specific period of time. Prevalence rates published in the sports injury literature include rates for specific conditions such as chronic brain injury among retired boxers, wrist pain among gymnasts, radiologic abnormalities of the thoracic-lumbar spine among swimmers, or scoliosis and fractures among young ballet dancers.

The two types of injury incidence most commonly reported in the sports injury literature are clinical incidence and incidence rates. *Clinical incidence* refers to the number of incident injuries divided by the total number of athletes at risk and usually multiplied by some *k* value (e.g., 100). In the sports injury literature, these rates have most often been presented as the number of injuries per 100 athletes but are also reported as the number of injuries per 100,000 participants, as seen in publications arising from the NCCSI. However, clinical incidence does not account for the potential variance in exposure of participants to risk for injury. For example, a sidelined or second-team player who sees little or no contact during a game is not at the same risk of sustaining injury as a healthy first-team player. During the past two decades, there has been a trend in the published literature for studies to report incidence rates rather than clinical incidence.

Incidence rate refers to the number of incident injuries divided by the total time at risk and usually multiplied by some *k* value (e.g., 1,000). It is the preferred measure of incidence in research studies because it can accommodate variations in exposure time of individual athletes. Different units of time at risk, varying in precision, have been used to calculate incidence rates in the recent literature. These include reporting the number of injuries per *k* athlete exposures (an athlete exposure is defined as one athlete participating in one practice or game in which there is the possibility of sustaining an athletic injury), per *k* time exposures (one time exposure is typically defined as one athlete participating in 1 hour of activity in which there is the possibility of sustaining an athletic injury), or per *k* element exposures (one element exposure is defined as one athlete participating in one element of activity in which there is the possibility of sustaining an athletic injury). Examples of exposure elements include vaults, pitches, bike trips, and climbs. The logistics of acquiring the appropriate data are usually a major factor in determining what the unit of risk will be and whether it will represent actual or estimated exposure.

A difficulty that may arise in comparing incidence rates from different studies relates to the injury definition employed. A review of the sports injury epidemiology literature reveals that few common operational definitions exist for injury. Definitions include criteria such as the presence of a new symptom or complaint, decreased function of a body part or decreased athletic performance, cessation of practice or competition activities, and consultation with medical or training personnel. Clearly, if injury is defined differently across studies, a meaningful comparison of injury rates is compromised due to different criteria for determining numerator values. Notably, soccer (football) and rugby unions have recently published methodological consensus statements that identify definitions and methodology to ensure consistency and comparability of results in studies examining injury in their sports. It is expected that consensus statements regarding injury research in other sports will follow.

Who Is Injured?

As might be expected, injury rates are most often categorized according to sports participation and the way in which participants are organized for sports (e.g., amateur or recreational, high school or college). In addition to participation level, injury rates are also reported relative to player position and gender. Given the variance in injury definitions across studies, perhaps the most reliable within- or across-sport comparisons arise from those studies that use a common, exposure-based injury definition and surveillance protocol and where certified athletic trainers and therapists or other health professionals record the injury data. Examples include research reports arising from the National Collegiate Athletic Association Injury Surveillance System, the Canadian Intercollegiate Sport Injury Registry (CISIR), and the U.S. High School Reporting Information Online system.

Where Does the Injury Occur?

Determination of "where" injury occurs involves identification of the anatomical and situational locations of injury. Anatomical locations include the body region of injury (e.g., upper extremity) as well as specific body parts (e.g., shoulder, ankle). Identification of commonly injured anatomical locations alerts sports medicine personnel to injury sites in need of special attention during preparticipation musculoskeletal assessment. Information on high–injury risk locations also provides important "targets" for preventive measures. For example, pursuant to the documented high risk of ankle and knee injuries in sports such as basketball and European handball, recent prevention studies have focused successfully on designing and implementing pre- and in-season proprioceptive and balance training programs. Similarly, the introduction of rules mandating the use of full face shields dramatically reduced the rate of facial and eye injuries in youth hockey. Most sports injury studies have reported injury location as a percentage value. However, some recent studies report incidence rates of injury for specific anatomical locations.

Environmental locations provide information on the distribution of injury by indicating where in the environment or setting the injury occurred. Environmental locations reported in the sports injury literature include the surface or terrain on which the activity takes place, such as natural grass versus artificial turf in soccer; the apparatus used or event, such as the balance beam or parallel bars in gymnastics; the geographical location, such as beach versus court volleyball; where on the court or field of play the injury occurred, such as the key in basketball; and whether the injury occurred during practice or in a competition. Information on high-risk settings is, of course, useful in identifying important subjects for further study, including the application of preventive measures.

Early research on environmental location reported place factors as percentage values. However, once again, more recent studies tend to report incidence rates. The importance of providing both types of information—percentage values and incidences rates—is perhaps best underscored by comparisons of injury between practice and competition. For many sports, the number of injuries incurred during practice is much greater than the number incurred in a competition, most likely because much more time is spent in practice than in competition. However, when incidence rates are compared, the common finding is a higher incidence of injury in competition. Competitors are much more likely to be playing at greater intensity and speeds in competition and tournaments than in practice, thus increasing the risk of sustaining an injury.

When Does the Injury Occur?

As Figure 3 indicates, the next characteristic of injury distribution is the *when* of injury occurrence. Time factors are typically expressed in terms of injury onset and timing of injury. There are two broad categories of injury onset that differ markedly in their etiology. Injuries that occur suddenly are often termed *acute* or *sudden-impact* injuries and are usually the result of a single, traumatic event. Common examples include wrist fractures, ankle sprains, shoulder dislocations, and hamstring muscle strain. Overuse injuries are more subtle and develop gradually over time. They are the result of repetitive microtrauma to the tendons, bones, and joints. Common examples include tennis elbow (lateral epicondylitis), swimmer's shoulder (rotational cuff tendinitis and impingement), Little League elbow, and shin splints. An injury history may actually involve both categories of injury onset, such as when an acute injury is superimposed on a chronic mechanism. However, this third injury category is not often distinguished in the epidemiologic literature on sports injuries. Most epidemiologic studies in the sports injury literature do not distinguish between acute and overuse injuries. However, this is an important oversight, particularly in etiological studies, given that the risk factors for overuse and acute injuries are not necessarily the same. The importance of identifying onset of injury is also important, given the growing evidence of overuse problems in sports, particularly among child and adolescent athletes. Baseline information on incidence of overuse injury is important if we are to fully comprehend the impact of these injuries and the role of injury countermeasures.

Examples of timing of injury include the time spent in practice, time of day, and time of season when an injury occurs. It stands to reason that if rates are higher during a particular time, then efforts to better understand the risk factors for increased incidence at that time are in order, and appropriate preventive measures should be applied to reduce risk during that time. For example, if the proportion of injuries is shown to be greater during the latter part of games, as has been shown in several studies and sports, then fatigue could be considered as a possible contributing factor. Although count data are sufficient to explore the relation between injury frequency and time in practice or competition for most sports, incidence rate data are necessary for a meaningful analysis of injury risk relative to time of season.

What Is the Outcome?

Injury outcome or severity can span a broad spectrum from abrasions to fractures to those injuries that result in severe permanent functional disability (i.e., catastrophic injuries) or even death. In the epidemiologic literature on sports injuries, injury severity is typically indicated by one or more of the following: injury type, time loss, residual symptoms, and economic costs. Assessment in each of these areas is important in quantifying the extent of the injury problem. It may be, for example, that injury incidence is similar in two sports; however, the severity of injury may vary considerably between these sports.

Injury Type

Identification of common injury types is important because it alerts sports medicine personnel to injury types in need of special attention (e.g., anterior cruciate ligament [ACL] injuries) and directs researchers in identifying and testing related risk factors and preventive measures. Most injury studies report injury types in general terms, such as contusion or fracture, with few specifics on the type of fracture, grade of injury, and so forth. Injury types are generally reported as percentage values; however, some recent studies also provide incidence rate values, particularly for specific injury types such as concussion, ACL injury, and so forth. This latter approach facilitates analysis of risk factors and preventive measures related to these injury types.

Time Loss

A useful measure of injury severity, and one often used in the literature on sports injuries, is the duration of restriction from athletic performance subsequent to injury. Most studies reporting time loss use days lost from practice or competition as a measure of injury severity. These time loss data are often categorized by time periods (e.g., 7 days or less), indicating the degree of severity. Although the use of days lost from participation may be among the more precise representations of injury severity in the literature, this approach is not without problems. For example, subjective factors such as personal motivation, peer influence, or coaching staff reluctance/encouragement may determine if and when players return to play. Accessibility to a health care professional and location of injury may also affect the decision of when to return to play.

Clinical Outcome

Clinical outcome includes factors such as reinjury, nonparticipation, and residual effects. An unfortunate outcome of many injuries, at all levels of sport, is reinjury. It is believed that unresolved residual symptoms from previous injury predispose an athlete to recurrent injury at the same site. As will be discussed in more detail below, an athlete with previous injury who returns to participation is characterized by a changed injury risk profile, particularly if the original injury has not been properly rehabilitated. Although few studies provide rate data for reinjury, it is noteworthy that many recent etiological studies of sports injuries include previous injury in their risk factor analyses.

Another important but infrequently researched aspect of injury outcome relates to the frequency of season- or career-ending injuries. An important question to address is how many athletes drop out of their sport, either temporarily or permanently, due to injury. This would seem an especially important area of interest in children's and youth sports where the number of dropouts is high. Data on season-ending injuries of young athletes in games such as football, gymnastics, cross-country running, and wrestling have been provided in a few studies.

Perhaps the most important question one can ask related to injury severity concerns the residual or long-term effects of injury. Although engaging in physical activity has many health benefits, there is also the risk of injury, which may have long-term consequences on the musculoskeletal system, resulting in reduced levels of physical activity. If residual symptoms are slight, they may only require the individual to modify his or her sporting level. In some cases, however, functional limitations resulting from injury may preclude further participation in sports. In extreme cases, such as catastrophic injury, serious physical damage may result in permanent, severe functional disability, such as quadriplegia, or even death. Surprisingly, with the exception of the NCCSI, which has been tracking nonfatal (i.e., causing permanent severe functional disability) and other catastrophic injuries in high school and college sports since 1982, few studies have reported on the long-term effects of injury. This is an important area of investigation given the potential for increased risk of osteoarthritis among injured participants, particularly those with injuries requiring surgery.

Economic Costs

Financial costs may be either direct or indirect. Direct costs are those incurred in conjunction with medical treatment (e.g., treatment, medication), and indirect costs are those associated with the loss of productivity because of increased morbidity and mortality levels. Although there have been several attempts to estimate these costs for a few selected sports and injury types, comparison of results has been hampered by differences in health care and wage compensation systems. Studies need to show how high the economic impact of sports injuries is on public resources in order to win the much needed funds for sports injury epidemiology research.

Analytical Epidemiology

In the past, good descriptive data have led directly to suggestions for injury prevention that, once implemented, have helped control and prevent the occurrence of severe sports injuries such as eye injuries in hockey and spinal injuries in football. Other preventive measures supported by research include improved training for high school wrestling coaches, increased awareness of pathogenic weight control in gymnastics, and rules against checking from behind in ice hockey. However, in the recent sports injury epidemiology literature, there has been a promising and observable transition to approaches that are etiologically rather than descriptively based.

Risk Factors

The epidemiologic approach to sports injuries is rooted in the assumption that injuries do not happen purely by chance, so an important part of sports injury epidemiology is the identification of the factors that contribute to the occurrence of athletic injury. It should be understood, however, that this process is not an isolated one. Risk factor analyses should be driven by a need to better understand the factors leading to injury in order to test and ultimately intervene with effective prevention strategies.

Risk factors may be classified as intrinsic or extrinsic. Intrinsic risk factors are individual biological and psychosocial characteristics predisposing a person to the outcome of injury, such as previous injury, strength, or life stress. Extrinsic risk factors are factors that have an impact on the sports participant "from without" and include factors such as the coach's qualifications, playing time, and surface conditions. Risk factors can also be divided into modifiable and nonmodifiable factors. Modifiable risk factors refer to those that can be altered by injury prevention strategies to reduce injury rates. Although nonmodifiable risk factors such as gender or age may be important considerations in many studies of injury prediction, it is above all important to study the factors that are potentially modifiable.

What complicates the identification and quantification of risks is that causality associated with injury is both extremely complex and dynamic in nature. Willem Meeuwisse and colleagues, in their article "A Dynamic Model of Etiology of Sport Injury: The Recursive Nature of Risk and Causation" (2007), proposed a dynamic recursive model that accommodates a multifactorial assessment of causation in athletic injuries and emphasizes the fact that adaptations occur within the context of repeated participation in sports (both in the presence and in the absence of injury) that alter risk and affect etiology in a dynamic, recursive fashion. In this model, intrinsic factors are viewed as factors that predispose the athlete to react in a specific manner to an injury situation. However, what is important to understand is that intrinsic factors are not constant and may change in response to injury or to absence of injury (i.e., adaptive changes such as increased intrinsic strength).

Once the athlete is predisposed, extrinsic or "enabling" factors such as faulty equipment, poor field conditions, or coaching behavior may facilitate manifestation of injury. For example, a quarterback who injured his shoulder during a tackle may have been predisposed to this injury by his history of previous shoulder dislocation (i.e., the intrinsic risk factor) and an enabling factor such as wet field conditions, which resulted in the athlete slipping and being tackled (i.e., the inciting event). According to the dynamic recursive model, extrinsic risk factors, like intrinsic risk factors, are also subject to change in the context of repeated participation in sports. For example, rule changes or equipment may result in risk modification, thus changing susceptibility to injury.

Analysis of sports injury risk factors has produced a number of significant injury predictors—including factors such as age, gender (specific to the sport and the type of injury), previous injury, and stressful life events—that have shown consistent results across multiple studies. However, much of the remaining body of literature suffers from one or more of the following limitations: (a) injury definitions and methods of injury data collection that are extremely variable, (b) use of clinical incidence rather than incidence rates (i.e., rates based on hours or sessions of exposure) to distinguish high-risk athletes, (c) failure to account for the different categories of injury onset, and (d) inappropriate analyses for detecting multifactorial risks. As a result, much of this research should be viewed as initial work in the important search for injury predictors, work that may provide interesting variables for manipulation in other study designs.

Injury Prevention

Once the analytical evidence points to an association between certain risk factors and injury, thereby establishing a degree of predictability for those participants who are likely to sustain injury, the next step in epidemiologic research is to seek ways to prevent or reduce the occurrence of such an injury (i.e., Step 3, Figure 2). Testing the suggested preventive measure to determine its effectiveness is an important aspect of the analytical epidemiologic process and fulfills the ultimate goal of epidemiology—prevention. Ideally, the effectiveness of injury prevention measures should be tested prior to recommending their general implementation.

The effectiveness of a preventive measure can most reliably be determined by employing an intervention study in which subjects are randomly assigned to treatment and control groups. Two general types of intervention studies are preventive trials and therapeutic trials. A therapeutic trial is conducted among subjects with a particular injury to determine the ability of an agent or procedure (e.g., taping, bracing) to diminish symptoms or prevent recurrence of that injury. A preventive trial involves the evaluation of whether an agent or procedure reduces the risk of incurring injury among those free from injury at enrollment in the study. In practice, there has been very little research designed to determine the effectiveness of injury prevention measures. Ethical, cost, and feasibility issues no doubt combine to preclude experimental research. However, the results of recent investigations of sports injury prevention strategies have been encouraging. Balance training appears to decrease the risk of lower extremity injuries, especially ankle injuries. Multiple interventions using warm-up and balance training are also effective. And the use of equipment such as breakaway bases, helmets, mouthguards, and face shields along with bracing of specific joints have resulted in a decrease in sports injuries.

Conclusion

Although sports injury epidemiology is a relatively new field, it has made great strides in the quest to prevent sports injuries. Advances in the field over the past 50 years include the following:

- Transition to approaches that are etiologically rather than descriptively based
- Publication of consensus statements that identify definitions and methodology to ensure consistency and comparability of results in studies examining injury in their respective sports
- Emergence and growth of multiple sports injury surveillance systems
- Increasing use of exposure-based injury rates (i.e., incidence rates)
- Increasing use of multivariate study designs with sufficient sample size
- Improvements in the number of large-scale, grant-funded studies
- Recent and successful initiatives of the Oslo Sports Trauma Center to organize World Congresses focusing on sports injury prevention

Existing epidemiologic research has already resulted in rule changes, equipment standards, improved coaching techniques, and better conditioning of athletes. However, many challenges remain. For example, there is a paucity of epidemiologic research in some sports with long Olympic histories and/or worldwide popularity, such as archery, canoeing/kayaking, and cross-country skiing. There is a need for national sport bodies to implement comprehensive sports injury surveillance systems. Otherwise, prospective, cohort studies are logistically difficult to initiate, leading researchers to use less robust designs. And finally, there is a need for translational research to examine the factors that influence the likelihood of a prevention strategy being adopted by the target population. In the future, sports injury epidemiologists also need to expend more collaborative effort to ensure that important research findings are successfully implemented and evaluated.

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See also Biomechanics in Sports Medicine; Preventing Sports Injuries; Risk Factors for Sports Injuries

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Epidural Hematoma

Epidural hematomas are a type of head injury involving bleeding into the space between the skull and the dura, the outermost layer of the protective structures surrounding the brain. They can occur as a sports injury when a traumatic force applied to the head is sufficient to cause a deformity of the skull and damage to the underlying middle meningeal artery. The high pressure of the blood coming from the arterial circulation causes the dura to separate from the skull, creating the classic lens shape hematoma that can expand quickly, placing significant pressure on the brain. They are a relatively rare type of head injury in sports, but epidural hematomas are very serious injuries that can lead to significant disability or death. Early recognition of the warning signs and quick medical attention are paramount to a good outcome.

Anatomy

The brain is protected inside the skull by three separate layers of tissue (*meninges*). The innermost layer, the *pia mater*, is a thin and delicate membrane that lies on the surface of the brain. The second layer, the *arachnoid mater*, covers the brain and pia mater but does not follow the contour of the involutions of the brain. The outermost layer, the *dura mater*, provides a thicker and tougher layer of protection.

These layers define three potential spaces for blood to collect. The *epidural space,* between the skull and the dura, the *subdural space,* between the dura and arachnoid layers, and the *subarachnoid space,* between the arachnoid and pia layers, each have their own potential sources of hemorrhage. The pia mater is too closely adhered to the brain and too fragile to act as a barrier for blood, and therefore, there is no potential space between the pia and the brain for a hemorrhage to form.

The epidural space is prone to blood collection due to the presence of a series of arteries that supply blood to the meninges, the *meningeal arteries*. The largest meningeal artery, the middle meningeal artery, is the source of most epidural hematomas because of its location near the temporal skull. Although the majority of epidural hematomas are the result of arterial injury (85%), they may also develop following injury to a meningeal vein or dural sinus, vascular structures that are also located in or near the epidural space.

Mechanism of Injury

An epidural hematoma can occur in sports as the result of an impact to the head. An epidural hematoma forms when the head impact is of sufficient force to either pull the meninges away from the inner table of the skull or cause a skull fracture. The vascular structures mentioned above, especially the middle meningeal artery, can be compromised in this setting, leading to bleeding and hematoma formation.

Given that the blood in the meningeal arteries is coming from the arterial side of the circulatory system and is, therefore, under high pressure, epidural hematomas typically expand at a much faster rate than hematomas that are formed from venous blood, such as subdural hematomas. The quickly expanding epidural hematoma increases intracranial pressure and can lead to damage of the underlying brain, brain herniation, or death.

Risk Factors

For an athlete, the baseline risk of developing an epidural hematoma is primarily a function of the type of sport being played, the equipment being used, and the playing technique of the athlete. While high-velocity contact sports, such as football, ice hockey, and lacrosse, may carry the most inherent risk, the use of proper equipment, especially helmets that meet the requirements set forth by the National Operating Committee on Standards for Athletic Equipment (NOCSAE), can greatly lower the risk. It is important to recognize, however, that epidural hematomas can occur in any sport in which an athlete experiences a head trauma. Certain sports that involve high velocities, less intentional contact, and little, if any, protective equipment, such as soccer and field hockey, may also pose additional risk.

Signs and Symptoms

The first sign of injury occurs shortly after the head impact and typically involves a change in consciousness. This change can span the spectrum from mild confusion to complete loss of consciousness. If the athlete remains conscious, he or she often has many of the signs and symptoms that are typically seen in concussion, such as headache, nausea, dizziness, and lack of coordination. The classic presentation of an epidural hematoma, however, involves what is known as the lucid interval. After the initial decrease in consciousness, which can last for several minutes, the athlete can improve significantly or even completely. During this time, the physical examination can be completely normal, and the athlete may appear unaffected. At this stage, the epidural hematoma is still small enough to be asymptomatic. As it expands, however, the increasing pressure inside the skull puts the brain at risk, leading to a quick return of symptoms. Continued expansion of the hematoma can then lead to rapidly progressive symptoms, coma, and even death. The lucid interval typically lasts only a few minutes, while the subsequent deterioration can occur even faster.

It should be noted that the presenting signs and symptoms of epidural hematoma are similar to those of other head injuries, including concussion. Often, the main difference is in the time course of symptoms. If any athlete develops new symptoms several minutes after a witnessed impact or if there is any perceived clinical worsening, emergency medical services should be notified immediately.

Clinical Evaluation

As with any athletic head injury, care should be taken on the field to first assess the "ABCs" (*a*irway-*b*reathing-*c*irculation) and evaluate the possibility of cervical spine trauma, instituting cervical immobilization when appropriate. Level of consciousness should then be noted using the Glasgow coma scale. Any language, memory, or orientation abnormalities should also be noted. A physical examination should then be performed to evaluate for skull fracture or any focal neurologic abnormality, including pupillary, visual field, and fundoscopic examinations, followed by a careful assessment of strength, sensation, reflexes, coordination, and gait. Any evidence of fracture or focal neurologic abnormality warrants activation of emergency medical services.

Following the on-field assessment, appropriate monitoring and serial examinations should be carried out to document any changes in signs or symptoms. If any worsening is noted, the patient should be further evaluated in a hospital setting. Care should be taken to establish an accurate timeline of events; the accurate documentation of findings will help clarify the athlete's postinjury course.

Diagnostic Tests

The presence of an epidural hematoma is usually confirmed with a computed tomography (CT) scan of the head. Magnetic resonance imaging (MRI) of the brain can also be used. While the MRI may provide more information regarding damage to the brain itself, it is more expensive, requires more time, and is not available at every medical facility. The initial diagnosis, therefore, is typically made with a CT scan. Acutely, epidural hematomas appear hyperdense (bright) on CT scan, are classically lens shaped, and are located in the temporal area.

Management

Athletes with a suspected epidural hematoma should be immediately transferred via emergency medical services to the nearest emergency facility. Once the hematoma is confirmed, the patient should be evaluated for surgical intervention. Surgery includes evacuation of the hematoma as well as repair of the vascular structures and skull, as needed.

Prevention

As with other head injuries in athletics, proper technique, well-fitted and certified equipment, and adherence to the rules of play are paramount in preventing an epidural hematoma.

Return to Sports

No athlete should return to participation in contact sports as long as he or she is still symptomatic from any head injury. In the case of an epidural hematoma, contact sports should be avoided indefinitely.

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See also Concussion; Head Injuries; Intracranial Hemorrhage; Neurologic Disorders Affecting Sports Participation; Subarachnoid Hemorrhage; Subdural Hematoma

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Epstein-Barr Virus, Infectious Mononucleosis, and Splenomegaly

Infectious mononucleosis (IM) accounts for considerable morbidity and even mortality in physically active young adults. In the United States, IM has a peak incidence between 15 and 21 years of age, and 1% to 3% of college students may become infected yearly. There is no evidence that IM is more prevalent or less prevalent in athletes.

Etiology

IM is caused by the Epstein-Barr virus (EBV), which is a member of the herpes virus family. It is excreted in the saliva and infects only humans. IM is transmitted by close contact between susceptible individuals and both symptomatic individuals and asymptomatic carriers, with an incubation period of 30 to 50 days.

Clinical Signs and Symptoms

Typical symptoms include a 3- to 5-day prodrome of headache, anorexia, and malaise, which is followed by fever, fatigue, nausea/anorexia, rash, exudative tonsillopharyngitis (may mimic streptococcal pharyngitis), tender lymphadenopathy (especially postauricular lymphadenopathy), hepatomegaly/hepatitis, and splenomegaly, typically lasting 2 weeks. Mild liver function elevation, atypical lymphocytosis (>10%), and heterophil antibodies confirm the clinical diagnosis. However, symptoms can be minimal and may be overlooked. In one study, less than half of the military cadets who converted from negative to positive serologically (IgG [immunoglobulin G]) for EBV had an illness over their 4 years of training that was clinically recognized as IM. Infection acquired during childhood often displays minimal or nonspecific symptoms, and many adults without a history of IM have antibody evidence of prior subclinical infection. The characteristic peripheral blood smear and monospot may be the only clinical diagnostic clues in those with minimal symptoms.

IM can cause rare neurologic, respiratory, hematologic, and/or cardiovascular complications. With the exception of the rare presentation of airway compromise, the most worrisome complication associated with IM is spleen rupture. A clinical dilemma for practitioners caring for these active patients involves determination of the timing for safe return to activity and the risk of spleen rupture. As lymphocytic infiltration and spleen enlargement occur in the first few weeks of infection, the normal tissue anatomy and support structures become distorted, increasing fragility of the spleen. This puts the spleen at risk for subsequent rupture, at times with minimal and/or no trauma involved.

Diagnosis and Management

Supportive evidence may be obtained from hematology or chemistry laboratory tests. Atypical lymphocyte count >10%, mildly elevated liver transaminases, and a positive heterophil antibody testing (monospot test) should confirm IM in a patient with a compatible clinical picture. If IM is suspected in a heterophil-negative patient or if a more exact time of disease onset is desired, EBV-specific antibodies (viral capsid IgM [immunoglobulin M], viral capsid IgG, EBV nuclear antigen) can be ordered.

In nearly all patients, IM is self-limited, and supportive care is the treatment for uncomplicated IM in athletes. The role of antivirals and corticosteroids in improving clinical status and reducing time until return to play remains unclear.

Spleen Rupture and Return to Sports

The increased morbidity and even mortality in patients without a functional spleen makes the decision-making process for return to sports after IM an important one. There are no studies published that accurately assess the risk of spleen rupture after IM. The risk of spleen rupture has been extrapolated from the general population studies to be approximately 0.1% to 0.5%.

Before athletes return to play, they should be afebrile, well hydrated, and asymptomatic, with no palpable liver or spleen. An approach toward rehabilitating the IM patient may be started as soon as the spleen is not endangered by the activity. If we could simply put our hands on the patient's abdomen and tell who was at risk for spleen rupture after IM, no clinical dilemma would exist. However, no studies presently exist that safely predict prospective risk. There is poor correlation in identifying splenomegaly by clinical history and examination, clinical symptoms, duration of illness, measured spleen size without baseline studies, or liver enzyme elevation. This makes it difficult to predict when an athlete with IM may safely return to full participation. The very sick, febrile, dehydrated athlete is an easy decision. It is the athlete with minimal symptoms who feels healthy enough to return to early competition who presents the clinical dilemma. Most IM spleens are enlarged, but not all are palpable, and most livers are neither enlarged nor palpable. There has been no definitive correlation identified between the enlargement of the spleen and blood liver/enzyme parameters. Accordingly, it is difficult to estimate spleen size or the risk of rupture of the spleen from blood values, assuming that the most enlarged organs run the greatest risk of rupture.

Imaging is generally not necessary, as it is not possible to estimate how safe it is for an individual patient to return to activity on the basis of absolute ultrasonography values, especially with the wide variability encountered in normal values. This is especially true considering that athletes tend to be at the extremes of size norms. If imaging is obtained to evaluate spleen size, ultrasound is preferable in that it is easy, noninvasive, and reliable and does not expose the patient to radiation. Further studies to correlate normal spleen size and body mass indices are needed. The judicious use of computed tomography (CT) or magnetic resonance imaging (MRI) may be useful in difficult cases when early return to play is contemplated.

The time frame for return to play after IM needs to be individualized. Despite the lack of evidence-based data to guide the decision-making process, some generalizations may be extrapolated from the limited literature and past clinical experience. There is a parallelism in the curves generated for the size of the spleen and liver and the blood tests that imply normalization within 28 days. Most spleen ruptures occur between the 4th and 21st day, with only a few occurring beyond 28 days after diagnosis. Based on the overall clinical impression, return to play after 1 month may be safe, but further studies are required to corroborate this clinical impression and the standardization of timing, as the insensitivity of the manual spleen examination and the rare reports of spleen rupture after 4 weeks are still areas of concern.

The decision for return to play after IM should be individualized on a case-by-case basis with recognition of all risk factors. All strenuous activity, weight lifting, contact sports, and even roughhousing should be limited in all patients with IM for the first 2 to 3 weeks. As previously mentioned, the spleen seems most vulnerable during the first 21 days, as most spleen ruptures generally occur during that period. Limited noncontact aerobic activity may be permitted beginning 3 weeks from diagnosis/symptom onset as long as the patient is afebrile, well hydrated, and asymptomatic, with no palpable spleen. This recommendation assumes that participants avoid any activities that put the spleen at risk for traumatic injury. The return to full activity must be individually paced, and abrupt changes in the progression of exercise should be avoided.

Conclusions

No strong evidence-based information supports use of a single parameter to predict the safe return to sports participation. The current consensus is that athletes be afebrile, well hydrated, and asymptomatic, with no palpable liver or spleen. Clinical judgment incorporating these criteria 1 month after diagnosis has been suggested as a safe predictor for gradual return to competition. These conditions for return to play do not guarantee that the spleen has returned to normal size and compliance or that the risk of spleen rupture has returned to baseline. For those athletes participating in contact sports who wish to return to sports in an earlier time frame or those with an equivocal examination, radiographic modalities may be used to help determine true liver and spleen size. Further studies are required to support this practice.

Kevin N. Waninger

See also Infectious Diseases in Sports Medicine; Young Athlete

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Erythropoietin

Erythropoietin (EPO) is a naturally occurring hormone that stimulates the production of new red blood cells (RBCs), a process called hematopoiesis. Athletes have used EPO to increase red blood cell mass as a way of gaining a competitive advantage, particularly in endurance sports.

RBCs deliver oxygen to peripheral tissues, including muscle. Exercising muscles use oxygen to produce energy. Well-trained muscles with adequate oxygen supplies can remain in aerobic metabolism longer. This means that the fuel that the body uses is metabolized efficiently with fewer waste products. Anaerobic metabolism (i.e., the breakdown and use of fuel stores in the body without the use of oxygen) occurs the longer the muscle is used and is much less efficient. In fact, during anaerobic glycolysis, only a small percentage of the potential energy is gained from each molecule of glucose used. In addition, lactic acid is produced as a by-product that builds up in the muscle. As more lactic acid accumulates, the muscle becomes sore, fatigued, and less efficient. Besides delivering oxygen, hemoglobin (a protein in RBCs) also acts as a buffer for lactic acid. EPO stimulates the production of more RBCs and so improves the potential for aerobic exercise metabolism.

EPO is a growth factor made primarily in the kidneys in response to hypoxia (low oxygen levels). Its production is stimulated by physical stress, such as exercise or exposure to high altitude where oxygen levels are lower. In fact, athletes have recently started to harness this phenomenon by sleeping in tents with slightly lower than normal oxygen levels to simulate high-altitude conditions and stimulate endogenous EPO. This method is considered safe if done properly and is legal with regard to competition.

EPO works by stimulating bone marrow to produce more RBCs and by improving the survival of existing RBCs. RBCs usually have a life span of about 120 days. In the setting of serious illnesses such as kidney failure or AIDS or during cancer chemotherapy, the life span can be shorter, and the production of new cells is diminished. The result is called "anemia of chronic disease." Recombinant, or synthetic, EPO has been used in medicine to treat this condition, and in future, it may have a role in treating certain brain injuries and in wound healing.

EPO has been abused by athletes as a blood-doping agent since the late 1980s, and has been banned since the 1990s. It is an injectable substance and can be effective for 6 weeks after administration. Sports governing bodies such as the World Anti-Doping Agency (WADA) employ several methods to expose and prevent doping with substances such as EPO. Certain athletes, such as competitive cyclists, have to agree to random searches of their homes or workout facilities for evidence of banned substances. Blood and urine tests are performed to search for traces of exogenous EPO, which is chemically different from naturally occurring EPO.

As an additional screening test, hematocrit and hemoglobin levels are measured in athletes. Hematocrit is the percentage of whole blood made up by RBCs. Hematocrit levels in healthy adults range from approximately 36% to 46%. Hemoglobin levels are expressed as the number of grams of oxygen-carrying protein per deciliter of whole blood. A normal hemoglobin range is 14 to 16 grams/deciliter. The use of EPO increases hematocrit and hemoglobin levels significantly. Allowing for individual variation and the fact that exercise increases these values, there are physiologic ranges for hematocrit and hemoglobin above which doping has to be suspected.

EPO use has significant risk. There are inherent risks from infection and adulteration of the product whenever an injectable chemical is used. In addition, there is a significant risk of complications from polycythemia, increased numbers of RBCs, and viscosity of the blood. Thrombosis (blood clots) can occur, leading to deadly pulmonary emboli, strokes, or heart attack.

Michael O'Brien

See also Doping and Performance Enhancement: A New Definition; Doping and Performance Enhancement: Historical Overview; Doping and Performance Enhancement: Olympic Games From 2004 to 2008; World Anti-Doping Agency

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Websites

UpToDate: http://www.uptodate.com

Exercise Addiction/ Overactivity Disorders

Exercise addiction or overactivity disorders can be diagnosed in patients who attempt to control their bodies and define their identity by overinvolvement in exercise activity. This overinvolvement often has addictive properties, thereby producing a rigid commitment to exercise routines, with symptoms of withdrawal when exercise is reduced or diminished. Experts estimate that at least 4% of Americans struggle with excessive exercise. While women are more often associated with eating disorders and a preoccupation with weight, it is men who are more likely to become addicted to exercise. College-age men are twice as likely as their female counterparts to exercise to excess. They are also more prone to becoming irritable and tense if there is a missed scheduled workout.

Symptoms

Warning signs of exercise addiction include exercising alone, a rigid exercise routine, exercising for more than 2 hours per day, a fixation on weight loss or calories burned, exercising when sick or injured, exercising to the point of pain and beyond, and skipping work or other obligations to complete exercise routines. The symptoms of exercise addiction and overactivity disorders are often the same as those for anorexia and bulimia. These overlapping symptoms are obsessive concerns over being fat, body dissatisfaction, and binge eating. The consequences of exercise addiction can be severe: Most excessive exercisers eventually develop overuse injuries, which can have long-term repercussions. Female exercise bulimics also cease to have periods, a condition called exercise amenorrhea. When a woman's menstrual cycles stop, it means her estrogen levels have dropped to those of a postmenopausal woman. Estrogen, of course, is vital for the normal development of bone—which reaches its peak in women in their mid-20s. If a woman's estrogen levels dip too low during this critical time, she may start losing bone mass instead of building it.

Symptoms that are solely concerned with overactivity are high levels of activity and feeling uncomfortable with rest or relaxation, dependence on activity for self-definition and mood stabilization, use of rationalization and other defense mechanisms to support involvement in an activity, fatigue, decreased concentration, reduction in performance, loss of emotional vigor, soreness, and stiffness.

Causes

Exercise addiction and overactivity disorders are most often associated with body image disturbance. Individuals with a healthy body image have positive self-evaluations and accurate perceptions about their body shape and size. Body image disturbance is marked by negative self-evaluations and is indicated when an individual's perceptions of shape and size differ from reality. Cultural body ideals are defined by the communications media and are largely unrealistic for the vast majority of the population.

Studies also indicate that overactivity disorders can be associated with depression, anxiety, and other mood-related disturbance. Compulsive exercise becomes a way to regulate negative feelings, and this may lead to excessive dependence on exercise.

Diagnosis

Currently, the American Psychiatric Association does not recognize excessive exercise and overactivity disorders as primary disorders. Excessive exercise is known to be a symptom of bulimia nervosa. The current *Diagnostic and Statistical Manual of Mental Disorders,* fourth edition text revision (*DSM-IV-TR*), describes excessive exercise as exercise that "significantly interferes with important activities, occurs at inappropriate times or in inappropriate settings, or when the individual continues to exercise despite injury or other medical complications." In the case of bulimia, exercise dependence is a way to control body weight, to maintain appearance, or to compensate for a binge-eating episode as opposed to or in addition to purging. This is known as non–purging-type bulimia nervosa. Rather than purging after episodes of binging, the bulimia patient fasts or exercises excessively to prevent weight gain or to achieve weight loss. Individuals with anorexia nervosa may also engage in excessive exercise as a method to achieve weight loss. There is a continuum of behavior known as excessive exercise and exercise dependence. Many researchers have concluded that exercise dependence occurs in the presence of a formal eating disorder. Other studies have indicated that exercise dependence exists in individuals without body image disturbance or with a preoccupation with thinness. They have concluded that it is a primary disorder that results in exercising for the sake of exercising itself.

Treatment

The treatment of overactivity disorders and exercise dependence varies according to the symptoms and the associated symptoms. Overactivity disorders can become quite dangerous if not addressed early on. It is important that a differential diagnosis be made between activity disorder with and activity disorder without the presence of an eating disorder.

Individuals with these disorders are often treated on an outpatient basis. Reducing physical activity, restoring it as a healthy behavior, and developing other coping tools to manage feelings of depression and anxiety are part of the treatment of these disorders. Seeking the guidance of a mental health professional and a physician is always recommended.

Sharon A. Chirban

See also Psychological Aspects of Injury and Rehabilitation; Psychological Assessment in Sports; Psychology of the Young Athlete; Sport and Exercise Psychology

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Exercise and Disease Prevention

Historically, physical exercise has been linked to conventional sports and associated with athletes. Currently, physical exercise is of great interest to many recreational practitioners, who enjoy exercise as a fun and useful way of improving health and well-being. The concept of exercise as a part of sports training has been extended to exercise as a means of improving the health of athletes. This entry will provide an overview of the role of exercise in disease prevention and of guidelines for performing health-related exercise.

The terms *physical activity, physical exercise,* and *physical fitness* are sometimes used interchangeably, although they are actually quite different concepts. *Physical activity* is any body movement produced by muscle action that increases energy expenditure. *Physical exercise* refers to planned, structured, systematic, and purposeful physical activity. *Physical fitness* is a set of attributes related to a person's ability to perform physical activities that require cardiorespiratory capacity, endurance, strength, or flexibility and is determined by a combination of regular activity and inherited ability. Another widely used concept is *health-related physical fitness,* consisting of those components of physical fitness that have shown a relationship with health. Health-related fitness has been characterized by an ability to perform daily activities with vigor and by traits and capacities that are associated with a low risk for the development of chronic diseases and premature death.

Role of Physical Activity/Exercise and Fitness in Disease Prevention

Physical Activity/Exercise and Disease Prevention

The Physical Activity Guidelines Advisory Committee, formed by the U.S. Department of Health and Human Services, in 2008 reviewed the existing scientific literature to identify the current evidence to develop a comprehensive set of specific physical activity recommendations. The review found strong scientific evidence that physically active people have higher levels of health-related fitness and a lower risk of developing a number of disabling medical conditions than do people who are inactive. These findings are summarized below.

Health Benefits of Regular Physical Exercise

Physical exercise reduces the risk of . . .

- early death
- developing heart and cardiovascular diseases
- developing obesity
- developing diabetes
- developing high blood pressure and high (bad) cholesterol
- developing certain types of cancer
- developing depression and anxiety

Physical exercise also . . .

- improves immune system activity
- tones muscles and preserves or increases muscular mass, preserving function and independence
- strengthens bones and joints
- increases coordination and balance, reducing the risk of falls and bone fractures
- helps in the control of body weight and improves “body image”
- promotes well-being and social integration

Health Benefits of Regular Physical Exercise

The review found that both children and adults benefit from regular physical activity. For children and adolescents, physical fitness and health status are substantially enhanced by frequent physical activity. Compared with inactive young people, physically active children and youth have higher levels of cardiorespiratory endurance and muscular strength, less body fat, more favorable cardiovascular and metabolic disease risk profiles, enhanced bone health, and reduced symptoms of anxiety and depression.

In *adults and older adults,* strong evidence demonstrates that more active men and women have lower rates of all-cause mortality, coronary heart disease, high blood pressure, stroke, Type 2 diabetes, metabolic syndrome, colon cancer, breast cancer, and depression than less active adults. In addition, physically active adults and older adults also exhibit a higher level of cardiorespiratory and muscular fitness, have a healthier body mass and composition, and have a biomarker profile that is more favorable for preventing cardiovascular disease and Type 2 diabetes and for enhancing bone health.

For *older adults,* strong evidence indicates that being physically active is associated with higher levels of functional health, a lower risk of falling, and better thinking ability. Regular physical activity also helps people with arthritis or other rheumatic conditions affecting the joints by improving pain management, function, and quality of life.

Physical Fitness and Disease Prevention

In adults, cardiorespiratory fitness is a powerful predictor of cardiovascular and all-cause morbidity and mortality. This is true for apparently healthy individuals and people with chronic diseases, such as Type 2 diabetes, hypertension, metabolic syndrome, and several types of cancer. This association is independent of adiposity, indicating that people who are overweight can benefit from improving their fitness level. Additionally, muscular strength, a component of physical fitness, may reduce the risk of death and of some diseases in adults, regardless of whether they are overweight/obese or not and whether they have a high or low cardiorespiratory fitness level.

Physical fitness also improves the health of children and adolescents. A recent review found that fitness reduces body fat and cardiovascular disease risk factors; reduces depression, anxiety, and fatigue; and improves skeletal health, self-esteem, academic performance, and quality of life in pediatric cancer patients/survivors.

Additive Effects of Physical Activity/Fitness and Other Risk Factors on Health Status

In addition to their individual effects on health status, low physical activity and low physical fitness often occur with other risk factors, leading to an additive negative effect on health. Obesity, for example, often occurs simultaneously with low physical activity and fitness. Individuals who are both obese and inactive/unfit have higher morbidity and mortality than those who are either obese or inactive/unfit but not both. Consequently, a change in one of those risk factors produces positive health benefits. Sedentary obese people who become physically active improve their health status, even if their weight status does not change. And those who both become physically active and lose weight achieve even greater health benefits. The debate about whether inactivity or obesity more strongly influences health status is not important from a public health perspective. The recommendation for both conditions is to increase physical activity.

Prescription of Exercise for Disease Prevention

There is little doubt that regular exercise benefits health. To help children and adults obtain these health benefits, the Physical Activity Guidelines Advisory Committee, on behalf of the U.S. Department of Health and Human Services, has provided specific recommendations for healthy physical activity in different populations.

Health-Related Exercise for Children and Youths

Children and youth should participate in 60 or more minutes of moderate to vigorous physical activity each day. Their activity should include the following types of physical activity on 3 or more days per week: (a) resistance exercise to enhance muscular strength in the large muscle groups of the trunk and limbs (e.g., push-ups, sit-ups), (b) vigorous aerobic exercise to improve cardiorespiratory fitness and cardiovascular and metabolic disease risk factors (e.g., cycling, walking, swimming), and (c) weight-loading activities to promote bone health (e.g., jumping, running).

Health-Related Exercise for Adults

The intensity of physical activity can be moderate or vigorous. Moderate-intensity activity is generally equivalent to a brisk walk that noticeably accelerates the heart rate. Vigorous-intensity activity is exemplified by jogging, and it causes rapid breathing and a substantial increase in heart rate. On average, 1.5 hours per week in moderate-to-vigorous physical activity will lead to a 20% reduction in risk of all-cause mortality, compared with less than 0.5 hour per week of moderate-to-vigorous physical activity. Additional amounts of physical activity are associated with additional reductions but at smaller magnitudes.

Current physical activity recommendations indicate that adults should do at least (a) 150 minutes (2 hours and 30 minutes) a week of moderate-intensity aerobic physical activity, (b) 75 minutes (1 hour and 15 minutes) a week of vigorous-intensity aerobic physical activity, or (c) an equivalent combination of moderate- and vigorous-intensity aerobic activity. Aerobic activity should be performed in episodes of at least 10 minutes and preferably should be spread throughout the week. Adults should also do muscle-strengthening activities, such as weight training, push-ups, sit-ups, carrying heavy loads, and heavy gardening, at least 2 days a week.

Health-Related Exercise for Older Adults

Because the exercise capacity of adults tends to decrease as they age, older adults generally have lower exercise capacities than younger persons. Thus, they need a physical activity plan that is of lower absolute intensity and amount (but similar in relative intensity and amount) than is appropriate for fitter people, especially when they have been sedentary and are starting an activity program. In contrast to what many people would think, the capacity for training and improvement in older people is, in relative terms, as high as in younger people. The current literature shows that strength gains after resistance training (8- to 16-week programs) in older adults (over 60 years) range between 10% and 82%.

For older adults at risk of falling, strong evidence exists that regular physical activity is safe and reduces falls. The programs of exercise for older adults should follow the same guidelines described above for adults but adapted to their possibilities. This exercise should include balance training, moderate-intensity muscle-strengthening activities, and participation in moderate-intensity walking activities. When older adults cannot meet the recommendations because of chronic conditions, they should be as physically active as their abilities and conditions allow. All older adults should avoid inactivity. Some physical activity is better than none, and older adults who participate in any amount of physical activity gain some health benefits.

Conclusion

Given the importance of physical exercise to general health status and disease prevention, people of every age, gender, and race/ethnic group should be physically active most days of the week and should strive to meet the new guidelines. Schools, sports centers, health organizations, and governmental institutions must work together to help people achieve this goal. Physicians should counsel their patients to be physically active and to meet the new guidelines.

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See also Benefits of Exercise and Sports; Exercise Prescription; Exercise Programs; Immune System, Exercise and; Mental Health Benefits of Sports and Exercise; Obesity; Pediatric Obesity, Sports, and Exercise; Women's Health, Effects of Exercise on; Youth Fitness

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Exercise and Heart Murmurs

Heart murmurs are extra sounds that originate from within the heart itself. Some murmurs are innocent and cause no problems for the patient, while others can be from dangerous or even life-threatening sources. Sometimes murmurs can affect exercise capacity and exercise tolerance—that is, how much or how long someone can exercise. Figuring out the source of the murmur can be a relatively easy process, but treatment varies greatly depending on the etiology.

Anatomy

The heart is composed of four chambers, two atria and two ventricles. The atria have thin muscle walls and help fill the ventricles completely with their contractions. The ventricles are larger cavities and have thicker muscle walls to help pump the blood either to the lungs or through the rest of the body.

Blood flows in from the body to the right atrium and passes through a set of valves, called the tricuspid valves, to the right ventricle. The right ventricle pumps the blood through the pulmonic valve to the pulmonary artery and then to the lungs. The blood returns to the heart into the left atrium and then passes through the mitral valve to the left ventricle. The left ventricle, the thickest of the four chambers, pumps the blood through the aortic valve to the aorta and out to the rest of the body.

Causes of Heart Murmurs

Murmurs can originate from innocent or concerning sources within the heart. Innocent murmurs are caused by the sound of blood flowing within the heart. To understand this more fully, it helps to think of the relationship of the left ventricle and the aorta (and the right ventricle and the pulmonary artery) as a large bucket and a pipe. The pipe is fixed to a wall, and the water is being thrown from the bucket into the pipe. Some of the water will go into the pipe and some will miss and hit the wall around the pipe. The same thing can happen in the heart. The left ventricle contracts with a powerful force, trying to force all the blood out of the aorta into the rest of the body. Not all the blood gets to the aorta with each contraction. Some of the blood misses and hits the wall of the heart around the aorta. This blood then swirls around in the heart, and this swirling can cause extra noise, which is heard as an innocent murmur.

Other heart murmurs come from sources within the heart—namely, the heart valves. (Certain genetic or congenital issues can also cause murmurs, but they are covered in another entry.) The valves in the heart normally open and close like a door, allowing the blood to go through at the appropriate times or preventing blood from passing when it should not. Valves can malfunction in one of two ways: They can become very stiff and not be able to open properly, or they can become loose and not be able to close properly. When valves get stiff, a condition known as *stenosis,* the blood has to pass through a smaller or narrower opening, which can cause extra noise and be heard as a murmur. When valves get loose, leading to a condition known as *insufficiency* or *regurgitation,* the blood can leak back through the incompletely closed valve and also cause extra noise, which can be heard as a murmur.

Diagnosis

Heart murmurs are diagnosed by a combination of physical examination and diagnostic imaging. During the exam, the physician listens to the heart with a stethoscope. Different types of murmurs can sound differently and have different qualities to them (loud, soft, harsh, blowing, etc.). Some other maneuvers, such as squatting and standing, can change the sound of the murmur and help determine what type of murmur is present. Sometimes the physical exam does not give the physician enough information to determine exactly what type of murmur is present. In these cases, an echocardiogram, an ultrasound test of the heart, is ordered. The echocardiogram will give information about the structure of the heart valves, whether the valves are functioning normally, and whether the blood flow is normal or altered.

Treatment

Identifying the cause of the murmur and the severity of the dysfunction determines how it will be treated. The echocardiogram results are combined with the patient's symptoms (shortness of breath, swelling in the legs, low exercise tolerance, etc.). Some innocent murmurs do not require any treatment, and the physician will follow the murmur over time to make sure it does not change. Other murmurs that are caused by the heart valves not functioning correctly but only mildly impaired may be treated with medications to help control the flow of blood and reduce the complications of the murmur. Some valves are moderately impaired, but the patient's symptoms can range from mild to very severe; the combination will determine if medications are enough. Then, there are times when the heart valves are severely impaired and need to be treated with surgery to replace the valve.

Heart Murmurs and Athletic Participation

The extent to which someone with a heart murmur can exercise depends on two main factors: the cause of the heart murmur and the patient's symptoms. Athletic participation guidelines have been developed for patients with different types of valve problems. The most recent update of these is published in the 36th Bethesda Conference on Eligibility Recommendations for Competitive Athletes With Cardiovascular Abnormalities. In general, the ability of a patient to exercise with a murmur is determined on an individual basis between patient and physician, taking into account the severity of the valve disease, the type of exercise desired, the patient's symptoms, and the overall health/other diseases of the patient.

David Berkson

See also Athlete's Heart Syndrome; Cardiac Injuries (Commotio Cordis, Myocardial Contusion); Congenital Heart Disease; Physiological Effects of Exercise on Cardiopulmonary System; Preparticipation Cardiovascular Screening; Pulmonary and Cardiac Infections in Athletes; Sudden Cardiac Death

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Exercise and Mitral Valve Prolapse

The mitral valve is located between the upper (atrium) and lower (ventricle) chambers of the left side of the heart. Normally, it allows blood to flow from the top to the bottom chamber only. *Mitral valve prolapse* (MVP) is a condition in which the mitral valve is loose and somewhat "floppy," so that it doesn't shut as firmly as it should. It may close with a faint click or may permit a tiny amount of blood to leak through, producing a heart murmur. A large prolapse can actually allow blood to seep back into the left atrium, a condition called *mitral regurgitation*.

Symptoms

Many people with MVP live their whole lives without symptoms. Those who do have symptoms may experience heart palpitations, chest pain, fainting, shortness of breath, decreased stamina, or fatigue with periods of weakness. These symptoms should prompt medical attention and evaluation.

Prevalence

Approximately 2% to 4% of the population has MVP to some extent. It seems to run in families, so a genetic component is likely, but this relationship is not clearly understood.

Diagnosis

These patients may be identified by using a stethoscope to listen over the anterior chest wall for certain sounds. Typically, patients with MVP may have a midsystolic click and/or murmur of mitral regurgitation. The diagnosis is usually confirmed by echocardiography to image the mitral valve and look for the abnormal structure and motion of the valve. An electrocardiogram is often done as well to look for evidence of irregular heart rhythms.

Complications

It should be emphasized that MVP is generally not considered to be a life-threatening or a progressive condition in the vast majority of patients. In fact, MVP is considered to be one of the most benign heart conditions that cause murmurs.

The two main concerns for those with MVP are the long-term effects of mitral regurgitation and the potential development of a heart infection called endocarditis. The backflow of blood from the ventricle to the atrium (regurgitation) can lead to enlargement of the cardiac chambers and weakening of the heart muscle. In rare cases, this can potentially lead to heart failure. Only about 5% of those with MVP have a large enough regurgitation to cause any problem.

Endocarditis is a rare but potential occurrence anytime there is an irregular or damaged heart valve. To decrease the risk of this infection, doctors prescribe antibiotics to patients with MVP before any procedure, such as dental work, that is likely to introduce bacteria into the bloodstream.

In general, the greatest risks for unfavorable outcomes with MVP, including severe progressive mitral regurgitation (requiring valve surgery) and endocarditis as well as (less commonly) strokes/emboli, dangerous arrhythmias, and sudden death, appear to be associated with severe, substantial structural abnormality of the mitral valve.

Recommendations for the Athlete

The heart is a muscle, and like any muscle, it gets stronger with exercise. Aerobic exercise strengthens the heart and makes it more efficient and is generally recommended for those with MVP if they do not have significant symptoms. In most cases, MVP is not a barrier to high levels of athletic performance and/or competition.

People bothered by chest pains or palpitations are sometimes given medications such as beta blockers. These drugs slow the heart rate during exercise. Active lifestyles can still be continued, and aerobic exercise is recommended with appropriate monitoring.

Sudden cardiac death due to isolated MVP is rare, particularly in relation to exercise and in trained athletes. Such events are probably not more frequent than in the general population and occur predominantly in patients older than 50 years with severe mitral regurgitation and/or systolic dysfunction. Some individuals with MVP appear to be part of a connective tissue spectrum disease expressed as a tall, thin habitus, thoracic cage deformity, and joint hypermobility for which there is a risk, albeit low, of progression to aortic dilatation or sudden death.

The following are recommendations for the athlete from the American College of Cardiology, as outlined in the 36th Bethesda Conference, 2005:

1. Athletes with MVP—but without any of the following features—can engage in all competitive sports:
   a. Prior syncope, judged probably to be of arrhythmogenic origin
   b. Sustained or repetitive and nonsustained supraventricular tachycardia or frequent and/or complex ventricular tachyarrhythmias on ambulatory Holter monitoring
   c. Severe mitral regurgitation assessed with color-flow imaging
   d. Left ventricular systolic dysfunction (ejection fraction less than 50%)
   e. Prior embolic event
   f. Family history of MVP-related sudden death
2. Athletes with MVP and any of the aforementioned disease features can participate in low-intensity competitive sports only as defined in the Bethesda Guidelines.

Christopher McGrew

See also Athlete's Heart Syndrome; Cardiac Injuries (Commotio Cordis, Myocardial Contusion); Physiological Effects of Exercise on Cardiopulmonary System; Preparticipation Cardiovascular Screening; Pulmonary and Cardiac Infections in Athletes; Sudden Cardiac Death

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Exercise During Pregnancy and Postpartum

Exercising prior to conception and continuing physical activity during pregnancy has many benefits for the mother and the child. Even if exercise is not begun until late in the pregnancy, exercise is beneficial as long as certain guidelines are followed.

Benefits of Exercise to the Mother

Regular exercise during pregnancy has many benefits. It helps the mother sleep better and improves the mother's energy and mood. It improves posture, muscle tone, strength, and endurance. It helps reduce backaches, constipation, and bloating. It may also help prevent or treat gestational diabetes and also help prepare a woman to cope with the pain of labor.

Effects of Exercise on the Fetus

In a healthy woman, there is little effect on the fetus during exercise. Extreme heat (≥102.5 °F) can be harmful to the fetus, but even with pregnancy increasing the mother's core temperature, exercising women have not been shown to routinely reach such extremes in temperature. In pregnant athletes performing intense exercise, fetal heart rates have been shown to remain normal. Even late in pregnancy, fetal oxygenation has not been shown to be impaired during intense exercise. The placentas of exercising women have improved blood flow and gas exchange efficiency for the fetus. There is a correlation between consistent weight-bearing exercise throughout pregnancy and reduced birth weight. Exercising women are more likely to experience labor a week earlier than sedentary women (not preterm labor), which may contribute to the lower birth weight of the child. Babies of exercising women have less behavioral and biochemical evidence of stress during late pregnancy and labor. Also, while the long-term follow-up data are limited, it appears that beginning/continuing weight-bearing exercise during pregnancy has no adverse effects on postnatal growth, health, or neurodevelopment, and in small studies, it has been shown to be even beneficial. Long-term studies are needed to better characterize such effects.

Maternal Changes During Pregnancy

Because there are many changes to a woman's body when she is pregnant, it is important to realize that these may affect the ability to perform certain types of exercise. The extra weight a pregnant woman carries will make her body work harder than prior to pregnancy. Her center of gravity is forward and upward because of her enlarging breasts and uterus, making it easier for her to lose her balance and also increasing her likelihood of back pain. The hormones produced during pregnancy cause the ligaments that support the woman's joints to be more relaxed, making the joints more mobile and at increased risk of injury.

Exercise can increase maternal core body temperature, but in general, pregnant women have a lower resting temperature and sweating threshold because of better heat dissipation (from plasma volume expansion, increased blood flow to the skin, and better heat exchange across the skin). Blood volume rises at 6 to 8 weeks' gestation and peaks to an increase of 40% to 50% by the middle of the second trimester. Cardiac output and stroke volume also increase, allowing exercise to be well tolerated in pregnancy. Such cardiac reserve decreases after 28 to 32 weeks' gestation, however, contributing to the need to decrease activity toward the end of pregnancy. Additionally, vigorous exercise usually is accompanied by increases in blood pressure and cardiac output. This response is blunted in pregnancy; thus, vigorous exercise would lead to shunting of blood away from the fetus and should be avoided.

Pregnancy leads to increased oxygenation, allowing pregnant athletes to achieve increased levels of oxygen consumption during exercise as efficiently as nonpregnant athletes. However, changes in maternal oxygenation are amplified in the fetus, so sustained maternal acidosis or hypoxia will eventually lead to fetal acidosis or hypoxia. Avoiding prolonged anaerobic activity can decrease this risk.

Before Starting an Exercise Program

It is important to review an exercise plan with the pregnant woman's physician before beginning, including the type of activity she would like to perform. Modifications may then be made to decrease risks of injury and fall and minimize extreme elevations in blood pressure and heart rate. If she is at risk for complications of pregnancy, including preterm labor, premature rupture of membranes, or vaginal bleeding, exercise is probably not safe. In addition, if she has conditions such as hypertension or diabetes, her exercise routine should be modified and monitored carefully, and medication adjustments may be needed. Thus, clearance from her doctor before beginning an exercise routine during pregnancy is extremely important.

Safe Exercise

Consensus on the safe limits of exercise during pregnancy is not easily obtainable. In general, for healthy women, the American College of Obstetricians and Gynecologists (ACOG) recommends 30 minutes or more per day of moderate exercise. Moderate exertion here means that the woman is able to talk comfortably during exercise (to keep her heart rate in an acceptable range). Walking, swimming, stationary cycling, and aerobics are all good exercises to choose. Running is acceptable in women who were runners prior to pregnancy, as long as balance is good and exertion levels are within range. Strength training can help improve muscle tone and reduce some of the aches and pains of pregnancy.

Exercise should be stopped immediately if the woman experiences shortness of breath, chest pain, dizziness, headache, muscle weakness, calf pain or swelling, vaginal bleeding, amniotic fluid leakage, preterm labor, or decreased fetal movement.

While no study has shown a negative effect of moderate-intensity aerobic exercise on pregnancy outcome, safe parameters have not been clearly established.

Exercises to Avoid During Pregnancy

Contact sports such as basketball, soccer, or hockey should be avoided because of the risk of abdominal trauma, with consequences to the mother and fetus. Sports with increased risk of falls (downhill skiing, ice skating, gymnastics, horseback riding, etc.) should also be avoided. Scuba diving is absolutely contraindicated because of the risk of fetal decompression sickness.

Safety Issues to Consider

If a pregnant woman is just starting an exercise program, she should begin slowly to acclimate to exertion. She should wear comfortable footwear and avoid rocky or unstable terrain when running or cycling. Because maternal joints are more lax in pregnancy, ankle sprains and other injuries may occur. She should drink plenty of fluids and avoid exercising in extremely hot weather. The risk of overheating can be minimized by wearing sensible clothing and avoiding saunas or hot tubs after exertion. Pregnant women should not exercise at altitudes above 6,000 feet (1,828.8 meters). Also important, pregnant women should remember to consume enough calories to compensate not only for pregnancy (about 300 extra calories daily [1 calorie = 4.2 joules]) but also for the added energy burned during a workout.

During the second and third trimesters, pregnant women should avoid exercises that involve lying flat on their backs, as this decreases blood flow to the womb. Exercise that involves standing upright for long periods of time should also be avoided. Avoiding the supine position after 20 weeks and avoiding excessive bouncing in the third trimester are reasonable precautions. By week 24, exercise should be tapered off according to tolerance and comfort level.

Postpartum Exercise

Many of the maternal physiologic changes during pregnancy remain for up to 6 weeks after delivery. Having a cesarean delivery, a difficult childbirth, or other complications may extend recovery time. Women have different recovery rates, so return to prepregnancy training regimen should be done gradually based on individual responses to exercise and after discussion with a doctor. Moderate weight reduction during nursing is safe and has not been shown to affect neonatal weight gain. In addition, exercise in the postpartum period is correlated with decreased risk of postpartum depression.

Conclusion

Each pregnant woman is unique and should be evaluated by a physician before starting an exercise program. The changes the mother and fetus undergo during pregnancy must be kept in mind when deciding on an exercise routine. This routine will need to be modified throughout the pregnancy, with avoidance of prolonged supine and prone positions toward the latter part of pregnancy. Contraindications to exercise exist, and physical activity should be stopped if warning signs occur. If exercise is performed wisely and cautiously, it can have positive effects on the mother and the child.

Kathryn E. Ackerman

See also Female Athlete; Mental Health Benefits of Sports and Exercise; Women's Health, Effects of Exercise on

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Exercise Physiologist

For decades, exercise physiology has existed as a research discipline within the context of several umbrella organizations. With the emphasis on research, exercise physiologists found themselves concentrating on publishing their findings, with little time devoted to the development of the profession of exercise physiology. Hence, the conversion from physical education to exercise science to exercise physiology is still evolving.

To help with the change process, the American Society of Exercise Physiologists (ASEP) was founded in 1997. The mission of the ASEP leadership is to promote ASEP as the professional organization of exercise physiologists to ensure the professionalism of exercise physiology. The leaders are committed to the professional development and credibility of exercise physiologists.

The researchers Peter Karpovich at Springfield College and Thomas K. Cureton at the University of Illinois, along with pioneers such as A. H. Steinhaus at George Williams College, John Holloszy at Washington University, Charles Tipton at the University of Iowa, and Phil Gollnick at Washington State, and the authors of exercise physiology textbooks (David H. Clarke of the University of Maryland, Harold B. Falls of Southwest Missouri State College, P.-O. Astrand of Stockholm, and Robert A. Robergs of the University of New Mexico, Albuquerque) have helped through their research to promote exercise physiology.

Professionalism and Exercise Physiology

Concern for health, fitness, and well-being has resulted in shared research efforts throughout the last half of the 20th century. Academic scholars in exercise physiology have helped other professionals to understand that regular exercise improves physiological, mental, and emotional health. Today, there are board-certified exercise physiologists (EPCs) with an interest in exercise as medicine, others who are interested in rehabilitation, and still others who are interested in health care or athletics.

The ASEP leadership has played a central role in gaining visibility and acceptance for exercise physiology as a credible health care profession. They developed the ASEP accreditation process, which defines exercise physiology. They also developed the board certification program to hold exercise physiologists accountable to a code of ethics and standards of practice.

In addition to protecting the public, the significance of the code is that students and professionals in the study and application of exercise physiology to health care and athletics can turn to it for guidance in professional conduct. Adherence is based on the belief that exercise physiologists are self-regulated, critical thinkers who are accountable for maintaining a high level of competence in the practice of exercise physiology.

Exercise physiology includes (a) the identification of the physiological mechanisms underlying physical activity; (b) the comprehensive delivery of treatment services concerned with the analysis, improvement, and maintenance of health and fitness; (c) the rehabilitation of individuals with heart disease and other chronic diseases and/or disabilities; and (d) the professional guidance and counsel of athletes and others interested in sports training and human adaptability to acute and chronic exercise. The ASEP defines an exercise physiologist as a person who has an academic degree in exercise physiology or who is board certified to practice exercise physiology.

Research and Scholarship

From a historical perspective, exercise physiologists were first physical educators who taught "physiology of exercise" in health and physical education departments. Since the earlier work with sports and athletics, exercise physiologists have been involved with research that deals with the integrated physiological responses of the mind and body.

There are many reasons for the interest in exercise physiology research. Among them are the benefits of understanding the physiology of regular exercise, how athletes adapt to training, and the rehabilitation of patients. Exercise physiology helps coaches and athletes understand oxygen consumption and what limits it, energy transfer and expenditure along with what constitutes a proper recovery, the oxygen transport system and weight resistance exercise, and the best way to develop sprinters and endurance athletes.

Exercise physiologists are also interested in diet, optimal nutrition, and athletic performance, as well as dehydration, heat problems, stress of altitude and thermoregulation, body composition, energy balance, and weight control. Their work has contributed substantially to a better understanding of the relationship between cardiac output and oxygen consumption ($\dot{V}O_2$). They helped develop and refine noninvasive carbon dioxide (CO_2) rebreathing procedures to measure cardiac output in their own laboratories and then set out to clarify the relationship and importance of heart rate (HR), stroke volume (SV), and arteriovenous oxygen difference ($a - \dot{V}O_2$diff) to improvements in exercise $\dot{V}O_2$.

Early exercise physiologists recognized the physiological relationship between the heart and lungs at rest and during exercise. Their work continues today with many papers dealing with the circulatory cost of breathing, expiratory flow limitations, pulmonary gas exchange, alveolar-to-arterial oxygen (O_2) exchange, ventilation-to-perfusion distribution, and the role of the respiratory muscles in endurance exercise. Many publications demonstrate an interest in aerospace physiology, particularly with reference to its effects on oxygen transport and lean muscle mass.

Whether it is evaluating the criteria for maximal oxygen consumption ($\dot{V}O_2$max) or the role of skeletal muscle mass, exercise physiologists have an interest in the determinants of $\dot{V}O_2$max. Whether it is a function of maximal cardiac output, blood volume, hemoglobin, or systemic tissue extraction, each area of study remains an important research question. Likewise, changes in the neuromuscular junction, muscle fiber hypertrophy, and chronic changes in skeletal muscle with aerobic and anaerobic training are important research topics, as are overtraining and the energy adaptations that occur with exercise.

Exercise as Medicine

At the heart of exercise physiology is the emphasis on exercise prescription, using $\dot{V}O_2$, metabolic equivalents (METs), HR, and rating of perceived exertion (RPE). Both aerobic training and high-intensity resistance training are associated with a lifestyle that decreases the risk factors for cardiovascular disease. When exercise is properly prescribed, not only does it help with the pathology of cardiopulmonary diseases, weight management, diabetes mellitus, osteoporosis, arthritic diseases, and neuromuscular diseases, but it also changes behavior, lowering the risk of premature disease and death. Exercise reduces the strain of stress, anxiety, and depression associated with stressful lifestyles. Increasingly, these findings have become a shared philosophy with health care professionals and scientists from various fields of study, including physicians, psychologists, psychiatrists, physiologists, biochemists, nurses, physical therapists, and other clinicians.

There are important adaptations to exercise both at rest and during exercise, especially the decrease in HR and the increase in SV to produce an effective cardiac output (Q) and increase the amount of oxygen available to the muscles for muscle contraction. There are also skeletal muscle changes (e.g., an increase in mitochondria, enzymes, fuel substrate, and myoglobin) that increase the work capacity of muscles. Maximal exercise changes include an increase in maximal SV, Q, and $\dot{V}O_2$max, in addition to larger expired ventilation volume and other changes that allow for greater physiological work.

As health care professionals, EPCs are researchers, educators, and clinicians. They provide health care services that help maintain, restore, and promote health and well-being. Their clients include anyone who is interested in better health and athletes who are engaged in sports training. Treatment is often in the form of exercise as medicine, whether it is for flexibility, strength, or endurance. They use metabolic analyzers to determine the client's $\dot{V}O_2$ and other physiological indicators of health and fitness. They may also consult and practice with a variety of other professionals for the rehabilitation of individuals with a wide range of symptoms and disabilities.

Tommy Boone

See also Careers in Sports Medicine; Exercise Physiology

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Exercise Physiology

Today's exercise physiologists are indebted to the rich history of academic programs in health and physical education. For many years, physical educators with an interest in sports physiology taught the "physiology of exercise" course in the college major. Significant concerns arose about the quality of the physical education major, resulting in many health and physical education departments changing to kinesiology or exercise science. Many of these departments offered doctorate degrees in kinesiology with a concentration in exercise physiology for the benefit of exercise physiologists.

Interest in exercise physiology in the United States developed during the 1960s, when exercise physiologists initiated adult fitness programs to increase physical fitness. During the 1970s, exercise physiologists worked with the medical community to develop cardiac rehabilitation programs to treat patients with myocardial infarction (MI). Additionally, many academic exercise physiologists actively engaged in research activities that focused on sports training to improve athletic performance. The prevailing view was that research is necessary to enable athletes to perform better. Advances in the scientific understanding of regular exercise and sports training support the value of exercise physiology.

When the American Society of Exercise Physiologists (ASEP) was founded in 1997 as a nonprofit professional organization of exercise physiologists, it was unclear to many in academia why it was needed. However, after decades of membership in nonexercise physiology organizations, academic exercise physiologists have become more aware that the students of kinesiology and exercise science majors experience considerable difficulty in locating credible career opportunities in the public sector. It is now recognized that research is only one component of exercise physiology.

The professional services rendered by the ASEP are important to instill professionalism in exercise physiology because of the challenges faced by exercise physiologists. In fact, to further encourage the professional development of exercise physiologists, the ASEP leaders introduced two electronic journals. Given the interest in research, the *Journal of Exercise Physiologyonline,* a peer-reviewed electronic research journal, was established in 1998 to feature original exercise physiology research, reviews, and editorials. Also, given that academic exercise physiologists prepare to become health care professionals, it was important to engage in discussions about professionalism. Hence, the *Professionalization of Exercise Physiologyonline* (*PEPonline*) was created in 1998. It was the first journal to publish articles on professionalism and professional development in exercise physiology.

Clarification of Titles

While it is common to hear exercise physiologists referring to themselves as "physiologists," the ASEP philosophy is driven by a more definitive and professionally appropriate title. For instance, since there is a doctorate degree in physiology, a person should not refer to himself or herself as a physiologist in everyday conversation unless he or she has that degree. This point and other similar inconsistencies have been published in *PEPonline.*

Similarly, since there is an undergraduate degree in exercise physiology, a person should not use the title Exercise Physiologist unless the person has that degree or has earned the EPC (board-certified exercise physiologist) credential. This is why a degree in exercise science or kinesiology is not a degree in exercise physiology, just as a physical therapy assistant cannot claim to be a physical therapist. To the ASEP leadership, this thinking plays a pivotal role in promoting the practice of exercise physiologists.

ASEP and Historical Perspectives

The ASEP leaders are aware that many exercise physiologists think of exercise physiology as a subdiscipline of exercise science. However, while exercise physiology could not have evolved into the profession it is today without the vision and work of its pioneers, the idea that it is an integrated science or a discipline that falls under exercise science is not true. Yet the ASEP leaders do not disagree that exercise physiology is an integration of many sciences. This thinking is integral to understanding its history and the context of exercise physiology as a health care profession.

Like other professions, the historical aspects are noteworthy, particularly in reference to the first exercise physiology textbook, *Physiology of Bodily Exercise,* by F. LaGrange in 1889, along with the first edition of *The Physiology of Exercise,* published by J. H. McCurdy, plus scientific work, research, and mentoring by Peter Karpovich

(Springfield College), Arthur H. Steinhaus (George Williams College), H. A. De Vries (author of the 1966 text *Physiology of Exercise*), B. Ricci (who published the 1967 text *Physiological Basis of Human Performance*), H. B. Falls (author of the 1968 text *Exercise Physiology*), Per-Olof Astrand and Kaare Rodahl (authors of the *Textbook of Work Physiology,* 1970), D. K. Matthews and E. L. Fox (authors of *The Physiological Basis of Physical Education and Athletics,* 1971), Thomas K. Cureton (University of Illinois), Elsworth R. Buskirk (University of Minnesota), John Holloszy (Washington University), Charles Tipton (University of Iowa), J. A. Faulkner (University of Michigan), Phil Gollnick (Washington State University), M. L. Pollock (University of Florida), Jack Wilmore (University of Texas, Austin), and D. L. Costill (Ball State University).

Clearly, this list represents only a small number of the contributors to exercise physiology. Many individuals, including textbook authors such as Bruce J. Noble, Michael Pollock, Scott K. Powers, and Edward T. Howley (authors of *Exercise Physiology*); Sharon A. Plowman and Denise Smith (the first female authors of an exercise physiology text, *Exercise Physiology for Health, Fitness, and Performance*); George Brooks (author of *Exercise Physiology: Human Bioenergetics and Its Applications*); William D. McArdle, Frank I. Katch, and Victor L. Katch (authors of *Essentials of Exercise Physiology* and other texts); and Robert A. Robergs (author and coauthor of several texts, including *Fundamentals of Exercise Physiology: For Fitness, Performance, and Health; Clinical Exercise Testing and Prescription Theory and Application;* and *Exercise Physiology: Exercise, Performance, and Clinical Applications*), have contributed significantly to the growth of the profession.

The difference between the 20th-century sports medicine perspective and the 21st-century ASEP perspective is that the ASEP leaders have declared their commitment to the professional development of exercise physiology as a health care profession, not just as a research discipline. This thinking is focused appropriately on the ASEP accreditation process that drives board certification, thus holding exercise physiologists accountable to their code of ethics and standards of practice. The significance of the code is that both students and professionals in their study and application of exercise physiology to health and wellness, rehabilitation, athletics, and sports training can turn to the code for guidance in their professional conduct.

Commitment to Professionalism and Scientific Thinking

Now that the ASEP leaders have defined exercise physiology as the identification of the physiological mechanisms underlying physical activity; the comprehensive delivery of treatment services concerned with the analysis, improvement, and maintenance of health and fitness; the rehabilitation of individuals with heart disease and other chronic diseases and/or disabilities; and the professional guidance and counsel of athletes and others interested in athletics, sports training, and human adaptability to acute and chronic exercise, there is every reason to think of exercise physiology as a profession. Also, since exercise physiologists have an academic degree in exercise physiology or are board certified by ASEP to practice exercise physiology, they are qualified to interpret the physiological effects of exercise and identify the appropriate modality (e.g., cycling, running, lifting) to individualize the exercise prescription.

Exercise physiology is a scientific profession with interests in sports training and exercise as medicine. The ASEP leaders believe that the increase in the elderly population will drive the demand for regular exercise for developing cardiorespiratory and muscular fitness for health purposes. The elderly population is particularly vulnerable to chronic and debilitating conditions that require the exercise physiologist's services. On the other hand, the baby boom generation is entering the prime age for heart attacks and strokes, which will further increase the need for cardiac and physical rehabilitation. It will be important that the services are rendered by credible professionals.

Widespread interest in health will increase the demand for exercise physiologists. That is why a growing number of employers use exercise physiologists to evaluate health and muscular fitness, develop exercise programs for special populations, and teach safe exercise prescriptions to their employees. They understand that an active lifestyle (especially regular aerobic exercise) protects one from many diseases, particularly coronary heart disease, by decreasing low-density lipoproteins (bad cholesterol), increasing high-density lipoproteins (good cholesterol), and reducing triglyceride levels. In short, epidemiological evidence supports the hypothesis that increased physical activity decreases the rate of death from heart disease.

Health Care Professionals

Exercise physiologists are set apart from personal trainers and fitness instructors. They understand and know all too well the importance of their scientific education and the fact that it is driven by laboratory experiences and the critical thinking necessary to design and oversee exercise prescriptions for clients and athletes interested in improving their health-related fitness and/or athletic performance. For these reasons, exercise physiologists are uniquely qualified to work with the apparently healthy population, whether in fitness centers or corporate settings. That is why they are qualified to supervise exercise programs and design wellness interventions and other models of rehabilitative care and secondary prevention through regular exercise.

Only EPCs have the academic and hands-on depth of knowledge that makes them the first-choice health care professional in designing effective exercise training for wellness enhancement, cardiopulmonary rehabilitation, and prevention of muscular and orthopedic problems (particularly in the ergonomic and occupational fitness settings with regard to adults suffering from arthritis, back pain, and osteoporosis). This is also true for the management of stress, anxiety, and depression, as well as for sports training and for prescribing and monitoring exercise and training programs for special populations, such as children and senior citizens.

The exercise physiologists' standards of practice provide a framework for understanding the educational requirements for attaining professionalism and recognition through the application of exercise as preventive medicine. There is little doubt that exercise is medicine, yet exercise physiology is often thought of only in terms of the physiological mechanisms underlying sports performance. In fact, it is clear that exercise physiologists' interest in competitive sports and the limits of athletic performance (particularly maximum oxygen consumption) is still of prime importance today.

It should come as no surprise that the work of the ASEP leaders is to encourage the use of exercise as medicine. They also believe that the best professional to supervise the exercise prescription is the ASEP EPC. For this reason and others, there is considerable interest in the professionalism of exercise physiology. In fact, for many college teachers who have been involved in the evolution of physical education from exercise science or kinesiology to exercise physiology, the drive to develop exercise physiology as a health care profession is intense. Exercise physiologists are responsible to the public, not just to athletes. At one end of the spectrum is health, and at the other end is a huge role in rehabilitation. It is the exercise physiologist's responsibility to know both ends of the spectrum. There is little doubt that the ASEP leaders are working hard to fulfill the 21st-century view of exercise physiology.

Exercise as Medicine

As credible professionals with a strong scientific background, exercise physiologists recognize the positive impact that regular exercise has on many clinical conditions, longevity, and good health. Regular exercise increases the ability of the body to transport oxygen for use by the muscles. Along with the increase in heart rate during exercise, there is an increase in stroke volume (blood ejected from the ventricles per beat) at the same cardiac output (volume of blood ejected from the ventricles per minute). Other changes include a favorable lipoprotein profile, increased bone density, and stronger ligaments and tendons. Endurance training results in myoglobin and glycogen adaptations, along with an increase in the number and size of mitochondria and the enzymes specific to energy development within skeletal muscles.

Regular exercise increases the capacity to engage in physical activity and plays an important role in primary and secondary prevention of cardiovascular disease. In particular, there is an independent blood pressure–lowering effect (in certain groups with high blood pressure) with a decrease of 8 to 10 mmHg (millimeters of mercury pressure) in both systolic and diastolic measurements. Also, regular exercise helps correct the independent risk factor of inactivity and its relationship to the development of coronary artery disease. Numerous studies indicate that blood lipid reduction, smoking cessation, physical exercise, and weight control significantly decrease the rate of progression and, in some cases, even allow for regression in the atherosclerotic lesions in persons with coronary artery disease.

Exercise physiologists are in the driver's seat with both an opportunity and a responsibility to promote regular exercise, as well as teaching and counseling lifestyle changes in risk factors for diseases and disabilities and other health promotion strategies. They not only teach about the health problems resulting from obesity, but are part of only a few professions that actually teach, measure, analyze, and publish data about body mass index (BMI). They argue, as others do, that physical inactivity and level of fatness are strongly related to watching television. That is why exercise physiologists teach that losing weight and keeping it off is most successfully done when exercising on a regular basis.

This is an important point since exercise physiology is the only profession with the word *exercise* in its professional title. This should persuade physicians and others to use exercise physiologists to assess a baseline body composition, to incorporate exercise for the purpose of losing weight and gaining lean mass, and to improve body image and self-esteem through regular exercise. Physicians should incorporate EPCs in their practice, as they have done with physician assistants, particularly with regard to cardiovascular assessment of patients and exercise prescription guidelines for a healthier lifestyle.

Exercise physiologists should be the scientific cornerstone in the multidisciplinary approach to managing, if not preventing, obesity. Excess body fat can significantly impair the health of children and adults. Obesity is directly related to heart disease and diabetes. While there are many factors that may cause obesity, from endocrine and genetic disorders to diet and inactivity, the latter factors are the primary contributors to the difficulty in managing caloric balance. Regular exercise is very effective in decreasing body weight by increasing energy expenditure, which is also related to a decrease in caloric intake. The exercise should be primarily aerobic activity and not resistance training, since more calories can be expended during a shorter exercise period.

Regular exercise is a viable, cost-effective treatment for depression. In fact, exercise compares favorably with individual psychotherapy, group psychotherapy, and cognitive therapy. For example, in 1996, the Surgeon General released a report on physical activity and health that concluded that exercise has a beneficial effect in relieving symptoms of depression and anxiety and in improving mood. Evidence was also presented that exercise may protect against the development of depression.

Exercise is also recommended as an adjunct treatment with the more traditional treatment programs for schizophrenia, conversion disorder, and alcohol dependence. The evidence is clear. Exercise is a cost-effective treatment for many behavioral health conditions. Exercise physiologists need to be encouraged to pursue jobs in this area of health care, and equally important, the directors and administrators of these programs need to look to exercise physiology for qualified health care professionals.

For decades, exercise physiologists have encouraged sedentary clients and patients to adopt a more active lifestyle through developing individualized exercise prescriptions and carrying out assessments, followed by recommending walking and low-intensity jogging as a mode of exercise. When exercisers comply with the prescribed program, the improvement in exercise capacity is multifaceted, with changes occurring in the cardiovascular, respiratory, musculoskeletal, and metabolic systems.

Specifically, there is a lowering of the myocardial work requirement and improvement in the peripheral factors that increase oxidative enzymes, which helps with the use of oxygen delivered to the working muscles. There is a decrease in the oxygen cost at the same submaximal exercise intensity that parallels the decrease in the work of the lungs (i.e., the metabolic cost of breathing). The latter is facilitated by an increase in tidal volume, a decrease in the frequency of breaths, and an overall improvement in alveolar ventilation. These changes and others help delay the metabolic disorders associated with aging.

EPCs also understand the importance of including resistance training in an exercise program to improve health, increase functional capacity and independence, and prevent disease. Resistance training prevents a decrease in skeletal muscle mass and function during extended periods of inactivity and aging. Research indicates that adaptation to resistance training lowers the cortisol response to acute stress, increases total energy expenditure and physical activity in healthy and frail older adults, and has beneficial effects on bone strength, osteoarthritic symptoms, high blood pressure, lipid profiles, and exercise tolerance in post-MI patients and others with coronary artery disease.

Exercise physiologists are leaders in the science of exercise prescription, whether it is the use of resistance exercise or aerobic exercise, for persons with cancer, acquired immune deficiency syndrome, chronic fatigue syndrome, fibromyalgia, or arthritis. They understand that a typical resistance training workout consists of 8 to 10 exercises to cover the major muscle groups (e.g., chest, shoulders, arms, back, abdomen, thighs, and lower legs) and that the resistance should be moderate, which is defined as 30% to 40% of 1 repetition maximum (RM) for upper body exercises and 50% to 60% of 1 RM for lower body exercises. When 12 to 15 repetitions can be accomplished with little difficulty, the weight is increased. This progressive resistance strategy meets the requirements of the overload principle, which is the basis for improvement in muscle strength. Similarly, exercise physiologists apply the overload principle in aerobic training through the interplay of the following variables: intensity, duration, frequency, mode, and progression type. When the scientific principles of the exercise prescription are followed, aerobic power ($\dot{V}O_2$max) is increased 5% to 30%.

Physiology of Exercise Testing

Exercise is a practical and easy way to develop and maintain a healthy mind and body. It can be done alone or in a group with others, and it can be started at almost any age with positive benefits. Because exercise is medicine, it should therefore be administered in a prescriptive manner as any medicine would be, and it requires professional knowledge and credible credentials. Unfortunately, this isn't the case among many personal trainers and fitness instructors who enroll individuals in exercise programs without the scientific knowledge or academic training they should have to ensure that the programs are safe and beneficial.

This point was highlighted by M. E. Ciccolella and colleagues in their presentation of an overweight, sedentary, and middle-aged man who suffered a heart attack during his first workout with his "certified" personal trainer. During the workout, the man repeatedly asked to stop because he was experiencing fatigue, heat, thirst, breathlessness, and chest pain. The trainer responded to requests to stop and complaints of fatigue by questioning his client's masculinity and by continuing the workout. In the lawsuit that followed (*Rostai v. Neste Enterprises*), Rostai sued the trainer alleging that the trainer's conduct breached a standard of care that caused the heart attack. Specifically, Rostai alleged that the trainer failed to properly assess Rostai's physical condition and cardiac risk factors and that the trainer's training approach was too aggressive. These failures, according to Rostai, constituted a breach of duty that caused the heart attack to occur during the workout under his trainer's supervision. Had the personal trainer understood the physiological basis of the exercise prescriptive process and the diagnostic importance of an exercise test, he would have concluded that it was unsafe to push Rostai as he did.

Exercise physiologists understand that a graded exercise test is associated with an increase in sympathetic nervous system activity to increase heart rate and cardiac output. Smooth muscles of the arterioles dilate to allow for the increase in cardiac output without an exaggeration in systolic blood pressure. The increase in heart rate and systolic blood pressure (known as double product) increases the work of the heart, which increases its need for oxygen (i.e., myocardial oxygen consumption).

The work of the heart is also increased as the sympathetic nervous system initiates a release of epinephrine from the adrenal glands, which increases ventricular contractility, resulting in a larger stroke volume. With the increase in heart rate and stroke volume, cardiac output is increased to match the need for more oxygen to produce energy (in the form of adenosine triphosphate, ATP) for increased muscle contraction. The increased extraction of oxygen at the cell level (i.e., arteriovenous oxygen difference, $a - VO_{2diff}$) is facilitated by the increase in capillaries around the muscle fibers, the diffusion of oxygen from the blood into the muscles, the metabolism specific to muscle fiber types, and the substrate (carbohydrate and fat) within the fibers.

The delivery of oxygen to the active muscles by the circulation is also aided by an increase in expired ventilation, which results from an increase in the frequency of breathing and tidal volume. Other respiratory adjustments in diffusion and the ratio of alveolar ventilation to lung perfusion ensure adequate gas exchange to saturate the pulmonary blood with oxygen. The end result is that the contributions from the lungs, heart, and vascular system to oxygen transport, along with the adjustments at the cell level, facilitate cellular metabolism. Overall, these physiological responses allow for the body's metabolism to increase to 10 to 12 times that of the resting measures.

At rest, oxygen consumption ($\dot{V}O_2$) is around 250 milliliters (ml)/minute, depending on body size and metabolism. For example, at rest, on average, cardiac output is 5 liters (L)/minute, and tissue extraction is 50 ml/L (or 5 ml/100 ml of blood). It is a simple matter of multiplying cardiac output (5 L/minute) by tissue extraction (50 ml/L), which equals 250 ml/minute. With exercise, $\dot{V}O_2$ may increase to 3 L/minute, or 3,000 ml/minute. This means cardiac output would increase from 5 to 20 L/minute and tissue extraction ($a - \dot{V}O_2$diff) would increase from 50 to 150 ml/L. Hence, the cardiovascular adjustment during exercise is both central (cardiac output) and peripheral ($a - \dot{V}O_2$diff). For example, cardiac output may increase in accordance with adjustments in heart rate from 70 beats/minute (bpm) at rest to 190 bpm during exercise, with stroke volume (i.e., amount of blood ejected per beat) changing from 70 ml at rest to 106 ml during exercise (i.e., 20 L/minute = 190 bpm × 106 ml). The stroke volume during maximal exercise for untrained males may approach 120 to 130 ml, while for trained males it may be 140 to 160 ml.

For highly trained, elite athletes, maximal stroke volume may reach, or even exceed, 200 ml. The values for women are lower than those for men. Maximal stroke volume for untrained and trained women is 100 and 120 ml, respectively. Blood pressure generated by the left ventricle helps ensure that the blood is ejected into the vascular system. It may average a maximum of 190 to 200 mmHg. Because blood pressure is directly related to afterload (i.e., systemic vascular resistance) and left ventricular wall stress, cardiac workload is significantly increased during exercise. For example, with a heart rate of 190 bpm and a systolic blood pressure of 200 mmHg, the heart's need for oxygen would be 380 ml $(100\ g)^{-1}$ $minute^{-1}$ compared with the cardiac work at rest of 84 ml (e.g., heart rate of 70 bpm and systolic blood pressure of 120 mmHg).

The graded exercise test provides a noninvasive method of estimating the integrity of the heart, given the linear increase in cardiac output versus oxygen consumption, with heart rate contributing more to cardiac output than stroke volume (since it tends to increase minimally above 40% to 50% of $\dot{V}O_2$max). EPCs use the test to design individualized exercise prescriptions to assess the physiological effects of an exercise program. It can also be useful in assessing the role of different medications and/or arrhythmias at rest and during exercise as well as the effectiveness of coronary artery surgery. Although the exercise test after an acute MI has been shown to be safe, the ASEP leadership believes that the test is safer when there is a physician alongside the exercise physiologist, especially when dealing with a decrease in the subject's blood pressure or if it should plateau after moving to the next stage. Also, if there are changes in the electrocardiogram (EKG) changes or chest pain or should the subject ask to stop the test, medical support is always available to assist the exercise physiologist.

While there are several different devices for testing, the treadmill is the most commonly used piece of equipment. The Bruce protocol is historically the preferred treadmill test, especially in cardiac rehabilitation programs. However, there are numerous other testing protocols used to evaluate the subject's functional capacity. The Balke-Ware is an excellent test because of its constant treadmill speed of 3.3 miles per hour (mph) (1 mph = 1.61 kilometers/hour approximately) and grade increments of 1% every minute. During the test, the exercise physiologist looks for indications to continue the test or contraindications to stop the test. Indications for stopping the test include ST-segment changes and premature ventricular contractions (PVCs) that suggest myocardial irritability due to ischemia.

Exercise Prescription

To prescribe exercise safely, knowledge of exercise physiology is required. This means more than taking an exercise physiology course. It requires a comprehensive knowledge and integration of the exercise physiology coursework. Specifically, prescribing exercise on an individualized basis requires knowledge of the following academic courses:

exercise physiology, psychophysiology, sports nutrition, applied anatomy, sports biomechanics, and resting and exercise electrocardiography, with specific information regarding acute and chronic adaptations to regular exercise. Knowledge of cardiovascular and muscular physiology, and the relationship of both to systematic work placed on the body, along with knowledge of health and/or medical status, age, and gender considerations with respect to kilocalorie and metabolic equivalents (METs), are necessary to develop safe, individualized exercise prescriptions.

In addition to an understanding of overload and specificity as foundational concepts for preparing individualized exercise prescriptions, exercise physiologists must demonstrate knowledge of the frequency, duration, intensity, and type of exercise, and progression. The physiological benefits that result from individualized exercise programs are directly related to the work placed on the body. Work is defined as the combined effect of frequency, duration, and intensity of exercise. Frequency of aerobic exercise should be at least three times a week with the possibility of increasing to four to five times a week after several weeks or even a month of regular exercise. Exercise sessions should be gradually increased from 20 to 45 minutes, with emphasis on low to moderate exercise intensity.

The exercise prescription for rehabilitation is based on the subject's physical performance during the exercise test. In general, the test is divided into three parts: (1) 5 to 10 minutes of warm-up, stretching, and range-of-motion exercises; (2) 20 to 45 minutes of intermittent or sustained exercise; and (3) 5 to 10 minutes of cooldown. Intensity is usually gauged by heart rate, although there are other methods (e.g., METs, $\dot{V}O_2$max, and rating of perceived exertion [RPE]). A number of different exercise modalities can be used. Patients may exercise entirely using the treadmill, or they may alternate between the treadmill and the bicycle ergometer. Regardless of the training approach, it is always advisable to begin exercise at a low intensity (30%–50% of maximal capacity) and progress accordingly (50%–70% of maximal capacity). Exercise at low to moderate heart rate intensity during treadmill walking for a longer duration is better than exercising at a high intensity for a shorter period of time. It is not only safer; it also allows for an increase in the use of fat as energy substrate.

Energy Metabolism

Energy is necessary for muscle contraction, which is critical for human movement. Chemical substances such as carbohydrates, lipids, and proteins (to a small degree) provide the energy for movement by muscle contraction. The nutrients yield usable forms of energy (a process called catabolism) from the chemical activities (i.e., metabolism) that take place in the muscle fibers. Since the body's metabolism is increased with exercise, the oxidation or breakdown of the nutrients is increased to provide more energy in the form of ATP. The catabolism of glucose by way of glycolysis and the Krebs cycle supplies the electrons that produce energy within the electron transport chain (ETC). Fats can also be converted to compounds that are intermediate products in the catabolism of glucose. Depending on the work that is required of the fiber, not all of the glucose undergoes glycolysis. Some is combined with other glucose molecules to form glycogen (this process is called glycogenesis). When there is an increased need for glucose as a source of energy, the stored glycogen is broken down into glucose to undergo glycolysis. This process of converting glycogen into glucose is called glycogenolysis.

The purpose of bioenergetics (i.e., the conversion of foodstuffs into usable energy-rich phosphate compounds such as ATP) is to ensure cellular energy production. With regard to exercise, the energy within the ATP molecule is used for muscle contraction. The compound itself is a combination of a molecule of adenine and ribose (referred to as adenosine) linked to three phosphates. The bonds of the two outer phosphates represent potential energy. When the enzyme ATPase breaks these bonds, energy is released to do work. Indeed, the hydrolysis of ATP to adenosine diphosphate (ADP), inorganic phosphate (P_i), and energy is critical to the sliding of filaments, known as *myofibrils,* and muscle contraction.

Since ATP is the universal energy donor for cellular work, cells must be able to produce it. Fortunately, there are several pathways to ensure a constant supply. The most immediate is the ATP-PC (phosphocreatine) system. The hydrolysis of PC, which is also written as creatine phosphate (CrP), regenerates ATP by giving its phosphate to ADP to form ATP. The enzyme creatine kinase (CK) is involved in the donation of phosphate to ADP.

This process does not require oxygen. It is entirely anaerobic. All forms of intense exercise (e.g., sprinting, weight lifting, and gymnastics) are possible because of the phosphagen system.

Another metabolic pathway that produces ATP is glycolysis. It is an anaerobic pathway that ends with the breakdown of glucose into two 3-carbon molecules of lactic acid. The amount of ATP produced by anaerobic glycolysis (net, 2 ATP) is small compared with that produced by aerobic glycolysis. Since the oxidation of one molecule of glucose yields 36 ATP (or 38 depending on the cytoplasm shuttle), the majority of the energy must be developed from a pathway other than glycolysis. That pathway involves the Krebs cycle, from which hydrogen ions and their respective electrons are carried by the electron-accepting coenzymes (nicotinamide adenine dinucleotide [NAD^+] and flavin adenine dinucleotide [FAD^+]) to the electron transport system, where the electrons undergo numerous oxidation-reduction steps until oxygen becomes the final electron acceptor.

The third pathway is defined as aerobic ATP production. It involves glycolysis, the Krebs cycle, and the ETC. Oxygen is not used in the Krebs cycle, but it is the final electron acceptor of the ETC. Both the cycle and the chain work together to produce ATP via oxidative phosphorylation. The Krebs cycle is concerned with the removal of carbon dioxide molecules and supplying electrons to the ETC. Carbon dioxide leaves the cell to enter the blood to eventually be exhaled via the respiratory system. The electrons are passed through a series of cytochromes that undergo numerous oxidation-reduction steps and ultimately reduce oxygen. Critical to the survival of each cell is the generation of ATP within the electron transport system via oxidative phosphorylation. ATP synthesis drives muscle contraction. The increased intensity of contraction requires an increased supply and breakdown of ATP, which controls the rate of NADH (reduced form of NAD) oxidation in the ETC. The rate at which glucose can be metabolized is controlled by the rate at which oxygen is available as the final electron acceptor.

The need for ATP drives ATP synthesis, which regulates the rate of electron transport. Hence, with the increased muscular activity of exercise, which requires an increase in the utilization of ATP, the transport of electrons coupled with more protons from the cytosolic side increases ATP synthesis. The increased hydrolysis of ATP in skeletal muscle results in an increase in the concentrations of ADP. The increased ADP and the increased regeneration (i.e., reoxidation) of NAD^+ stimulate the Krebs cycle. As long as there is adequate oxygen at the cell level, the rate of ATP development is adequate to meet cellular metabolism. If there is inadequate oxygen to accept the electron flow—that is, if the energy demand exceeds the ATP production rate of the ETC—the reduced electron carriers, NADH and $FADH_2$, begin to accumulate. NADH can be oxidized to NAD to keep glycolysis operating for another minute or two at high-intensity exercise. Increasingly, then, energy for skeletal muscle work must come from anaerobic metabolism.

Knowledge of exercise metabolism is critical to designing an appropriate exercise program and prescription for clients and a training program for athletes. From gymnastics and sprinting to swimming and running, it is important that the exercise physiologist have a thorough knowledge of the three energy systems and the underlying cardiorespiratory physiology that supports cellular metabolism.

The Future

Health care issues and athletics represent a huge industry, with much riding on the professionals who help prevent fitness-related problems in clients, patients, and athletes, assisting in their rehabilitation and keeping them working, playing, and enjoying life. Unfortunately, there are too many "weekend warrior" personal trainers and instructors who aren't academically qualified to help athletes with knee problems or guide a post-MI patient safely in rehabilitation. Exercise physiology as a health care profession is thus relevant not only to college and professional athletes but also to young children with obesity and adults who do not have the knowledge to develop and/or maintain cardiovascular and muscular fitness. EPCs help by filling the void of decades past. Now, with accredited academic programs of study, they are credible professionals with state-of-the-art research- and evidence-based skills to work with the sports medicine community in developing health care programs for all individuals, including special populations (female, pediatric, older adults), employing rehabilitation regimes, nutrition, biomechanics, and applied anatomy to help them maintain a healthier lifestyle.

Tommy Boone

See also Benefits of Exercise and Sports; Bioenergetics of Exercise and Training; Cardiovascular and Respiratory Anatomy and Physiology: Responses to Exercise; Exercise Physiologist; Physiological Effects of Exercise on Cardiopulmonary System

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Exercise Prescription

With the American College of Sports Medicine's (ACSM's) recent release of the "Exercise Is Medicine" campaign, the role of exercise in health has been highlighted. The question now becomes "How should people exercise?" The answer is in the exercise prescription. An *exercise prescription* is a medical recommendation of exercise, including aerobic activity, resistance training, and stretching, for the purpose of achieving better health or an additional desired fitness benefit. It can be prescribed by physicians and other certified fitness experts, depending on the health of the patient. This entry discusses the key points of the exercise prescription.

Benefits of Exercise

Before prescribing exercise, it is important to define exercise and its importance to one's health. In essence, any activity that increases one's aerobic capacity, strength, and/or flexibility is exercise. Aerobic exercises, such as walking, jogging, cycling, swimming, dancing, and rowing, operate within the oxidative pathways; thus, proper breathing and adequate hydration and nutrition are important. Resistance training works to gain muscle mass, endurance, and strength and also depends on proper breathing and correct technique. Using free weights, weight machines, and/or elastic bands and tubing, individuals can perform several different types of resistance exercises, including isotonic, isokinetic, and isometric exercises. When counseling patients on resistance training, it is important to highlight the potential for delayed-onset muscle soreness. Stretching exercises, of which yoga and tai chi are currently popular, can be performed as static stretching exercises, as ballistic stretching exercises, or as proprioceptive neuromuscular facilitation exercises. An exercise prescription should include all three main types of activity: aerobic, resistance, and stretching.

The benefits of exercise extend to all those who participate and include the following: (a) decrease in all-cause mortality, (b) decrease in cerebrovascular events, (c) decrease in risk of cancer, (d) decrease in risk of Type II diabetes mellitus, (e) decrease in complications of Type II diabetes mellitus, (f) decrease in high blood pressure, (g) decrease in bone loss over time, (h) increase in strength and balance, (i) improvement in lipid profile (increased high-density lipoproteins, decreased triglycerides and low-density lipoproteins), (j) maintenance of optimal weight for health, (k) decrease in anxiety and depression, and (l) economic benefits to the individual, the community, and the workplace (decreased absenteeism, disability, and medical costs).

Although replete with benefits, exercise is not without its risks. The most concerning risk of exercise is the risk of exercise-related sudden death; those with coronary artery disease, hypertrophic cardiomyopathy, and recent acute myocardial infarction have two to six times this risk when compared with healthy individuals, whose risk is small. Additional risks of exercise include the risk of musculoskeletal injury, particularly sprains and strains, which depend on the individual's age and the exercise activity. Metabolic disorders can also occur with exercise, including hyperthermia and hypoglycemia. Last, exercise can result in hematologic disorders, such as hemoglobinuria, hematuria, and rhabdomyolysis.

Before Writing an Exercise Prescription

Once one has an understanding of exercise, its benefits, and its risks, one is ready to write an exercise prescription. Before beginning, it is important to know your patient! The age of the patient will alter the activities you prescribe. In addition, the patient's health history might further limit available activities. Particular attention should be paid to patients with the following medical conditions: cardiac disease, asthma and other pulmonary disorders, pregnancy, old age, osteoarthritis, and metabolic diseases, including obesity and diabetes mellitus. Not only might those patients require limited activity; their exercise activities might need to be supervised, such as within a cardiac rehabilitation program, and their interim follow-up visits might need to be more frequent. Exercise is contraindicated in patients with a history of recent acute myocardial infarction, unstable angina, dangerous dysrhythmias, aortic dissection, acute congestive heart failure, severe aortic stenosis, myocarditis, pericarditis, thrombophlebitis, intracardiac thrombi, pulmonary embolus, acute infection with fever, severe subaortic stenosis, complicated pregnancy, and uncontrolled metabolic disease.

Knowing the patient can extend beyond obtaining a health history. A physical exam and exercise testing might also be warranted, depending on the patient's age, health status, and risk factors for exercise-related sudden death. It is also important to assess the patient's readiness to participate in exercise activities. Is the patient in the precontemplative stage and therefore not even considered exercising; has the patient entered the contemplative stage, perhaps buying exercise equipment or exercising occasionally; or does the patient actively exercise on a routine basis? While discussing exercise with your patient, it is important to address any roadblocks to activity, particularly for precontemplators and contemplators, as well as previous exercise preferences and current exercise goals.

When prescribing exercise, one must also be aware of the current physical activity recommendations. ACSM and the American Heart Association (AHA) released new recommendations for physical activity in 2007. The ACSM/AHA 2007 recommendations focus on aerobic activity and resistance training. Aerobic activity can be moderate or vigorous in intensity, and the duration of activity depends on the intensity. Currently, it is recommended that healthy adults under age 65 participate in moderately intense aerobic activity for 30 minutes' duration at a frequency of five times per week. If the activity intensity is vigorous instead, it need last only 20 minutes in duration at a frequency of three times per week. Strength training, a new recommendation, involves 8 to 10 exercises performed at 8 to 12 repetitions at a frequency of two times per week. Also included in the 2007 recommendations, and varying per the patient's health status, are balance training and a monitored activity plan.

How to Write an Exercise Prescription

With the ACSM/AHA 2007 recommendations in mind, physicians and certified fitness experts should use the FITT principle when prescribing exercise. FITT is a useful mnemonic that stands for frequency, intensity, time, and type. The frequency determines how often the individual should exercise. Intensity designates how challenging the activity should be. Time describes how long the activity should proceed. Type defines the exercise activity itself. When considering an exercise program for a patient, it is also important to contemplate the patient's rate of progression within the exercise program, moving from an initial conditioning phase, to an improving conditioning phase, and, finally, to a maintenance condition phase. In general, it is better to increase the frequency first, followed by an increase in the duration of the activity. The last element to be increased is the intensity of the exercise.

Although the FITT mnemonic is helpful, one must alter the exercise prescription in the case of special populations (i.e., individuals with the conditions listed above as risk factors for exercise-related sudden death). Cardiac patients may require a multiphase rehabilitation program of graduated exercise, during which physical activity is physiologically monitored (via heart rate monitoring, assessment of the rate of perceived exertion, and electrocardiogram) and accompanied by significant patient education. Patients with arthritis might benefit from hydrotherapy. As exercise is a means of blood glucose control, diabetics would need to monitor their blood sugar for hypoglycemia, the most common side effect of exercising with diabetes. They may also need to adjust the types of activities they perform, should their diabetic neuropathy affect their balance or gait. Patients with hypertension, dyslipidemia, and obesity can generally follow the general guidelines; however, it must be noted that these conditions usually do not occur alone.

Conclusion

Exercise involves activities that increase aerobic capacity, strength, and/or flexibility. Physicians and certified fitness professionals should use the FITT principle when prescribing exercise. In addition, they must consider the patient's current health status, readiness to participate, and exercise preferences, as those issues may affect the patient's ability to participate in and respond to exercise.

Nailah Coleman

See also Aerobic Endurance; Benefits of Exercise and Sports; Circuit Training; Conditioning; Cross-Training; Exercise Physiology; Exercise Programs; Group Fitness Instructor; Home Exercise Equipment; Mental Health Benefits of Sports and Exercise; Obesity; Presports Physical Examination; Principles of Training; Resistance Training; Weight Loss for Sports

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Exercise Programs

Exercise is a potent stimulus to the human body, which, over time, can mediate changes in physiological structures and function. Although a single workout can create acute exercise stress, exercise training is the repeated use of a workout over time to achieve a specific fitness goal or health outcome. The outcomes of a training program will be specifically related to the program design of the workout. This underscores a major principle in exercise physiology, namely, *specificity of training*. Therefore, the outcomes of any exercise program will be specific to the type of workouts used and their ability to appropriately stress the physiological systems that they are targeting. Understanding the variables associated with exercise program design can provide insights into the creation of the exercise stimuli, which with training will alter function, improve structure, and ultimately enhance a specific health or fitness outcome.

While there are many different forms of exercise, the two major domains are related to cardiovascular endurance training and resistance training. Each of these exercise modes has a host of different types of programs within its domains, but they act as the two major forms of exercise used in all training programs. Endurance training is primarily directed at improving the cardiovascular system, while resistance training is directed at improving the neuromuscular system. In the process, each type of exercise program can have dramatic effects on other physiological systems, such as improving insulin resistance or enhancing toleration of metabolic acidosis. Ultimately, it always comes down to the specific exercise prescription used in a training program and its ability to stimulate the appropriately targeted physiological systems.

Finally, exercise prescriptions and training programs must be individualized so as to meet the needs of each person and be appropriate for his or her age, fitness level, and functional capacities to exercise. This type of individualized programming requires a careful medical screening, goal determinations, preliminary testing, and a needs analysis to have initial data from which to make program design decisions.

Cardiovascular Endurance Training Programs

Aerobic exercise is targeted at developing cardiovascular fitness and health. Maximum oxygen consumption ($\dot{V}O_2max$), or the amount of oxygen that can be extracted from the blood for use by tissues, primarily skeletal muscle, is one of the most common measures of aerobic fitness and the target of aerobic endurance training programs. Additionally, cardiovascular conditioning promotes ultrastructural adaptations in the heart (e.g., increased ventricular volume, increased collateral circulation in the heart) and improves peripheral tissue adaptations (e.g., increases in capillaries, improved insulin resistance, increased metabolic enzymes, increased numbers of mitochondria). Thus, the improvement of maximum oxygen uptake is mediated by many associated adaptations in the neuroendocrine and metabolic systems along with structural changes in the vascular system.

Variables in Program Design

An exercise session will typically start with a light warm-up (low-level exercise and stretching) and end with a cooldown (e.g., low-level exercise followed by stretching) to allow for a gradual increase and decrease in muscular activity and metabolic intensity.

The basic variables of an endurance training program design are as follows:

1. *Intensity:* This typically refers to the percentage of maximum oxygen consumption or percentage of maximum heart rate or heart rate reserve that results in a heart rate range for each individual to target during the exercise session. Exercise is typically done in a continuous form, but in some cases, intervals training might be used for more advanced athletic training programs. Ratings of perceived exertion (RPE) using the classic 6 to 20 Borg Scale can also be used to modify the intensity, especially when the heart rate range is predicted (e.g., using the Karvonen formula) rather than obtained directly from a graded exercise test (American College of Sports Medicine [ACSM], 2006). Program guidelines: Exercise with a target of 60% or 70% of the predicted maximal heart rate (HRmax = 220 – age) or 50% to 85% of the $\dot{V}O_2max$ when directly determined from a graded exercise test or 50% to 85% of the heart rate reserve (Karvonen formula: [(HRmax – HRrest) × %Intensity + HRrest]). The key is to target a lower range, with peak heart rates not going over the upper limit. With a graded exercise test for patient populations, the function capacity is set clinically at the upper limit where no ECG or symptoms exist.

2. *Frequency:* This refers to the number of times per week an exercise session should be planned. The ACSM recommends a frequency of three to five exercise sessions per week. For beginners, 48 hours of rest between exercise training sessions is recommended, and for advanced programs where exercise training is done each day, careful variation/periodization in the program whereby the same workout volume and intensity are not used each time is needed for optimal progression.

3. *Duration:* This refers to the length of time that an activity should be continued. The ACSM recommends that an exercise session be performed for between 20 and 60 minutes, not including warm-up and cooldown activities.

4. *Volume:* This refers to some measure of total work, including miles or kilometers covered, number of intervals, number of steps, and so on. The volume becomes an important factor in varying the training sessions.

5. *Mode:* This refers to the type of exercise used. Typically one uses whole-body exercise modes if both the upper and lower body muscles are capable of movement. Exercises such as running, jogging, stepping, cycling, swimming, cross-country skiing, aerobic dancing, and step aerobics are used to stimulate whole-body metabolism and the needed heart rate responses. When testing for fitness levels, one needs to keep in mind mode-specific testing, taking the modality that is most frequently used. For advanced athletes, using the same modality may be required, but careful variation/periodization is needed to avoid injury and overtraining.

Progression of the Aerobic Exercise Prescription

Each exercise training program should be individualized. For the fitness enthusiast, the activity should be enjoyable, especially for the average person interested in lifelong fitness and health outcomes. Cross-training using different modes of exercise can also help avoid overuse injuries and keep the exercise training fun. The exercise should start at the lower end of the prescription until physical and mental toleration is achieved. If the person is highly deconditioned, it should even start lower. A classic concept, "doing too much too soon," is a major reason for early program injuries and/or overtraining even in advanced athletes. Program variation or periodization of the intensity and volume is becoming more important in modern conditioning programs. This means that doing the same activity day in and day out is not optimal to recovery or adherence. Thus, one day one might do a higher volume at a lower intensity, the next day do a lower volume at a higher intensity, and the next day use a different modality with moderate volume and intensity.

Resistance Training Programs

Resistance training is the next major type of training program. Again, with the many possible programs that can be designed, one has to carefully determine the goals and needs of the individual and develop a resistance training program that will address those needs. Typically, the goals of a training program are for strength and power and the associated muscular hypertrophy. Local muscular endurance is also a trainable characteristic. Again, many associated adaptations occur in different tissues depending on the program design (e.g., increased bone density, improved stair-climbing ability). In addition, reduced peripheral stress on the heart and better toleration of metabolic stress due to stronger muscles and improved functional capabilities can also be observed.

Training Principles

Again, some general training principles must be kept in mind when designing a program.

1. *Specificity of training:* Only the muscles that are trained will adapt and change in response to a resistance training program. For this reason, resistance programs must target all muscles for which a training effect is desired.

2. *SAID principle: S*pecific *a*daptations to *i*mposed *d*emands relate to the fact that the adaptation will be specific to the demands that the characteristics of the workout place on the individual. If a high number of repetitions are used, the muscles will increase their ability to perform a high number of repetitions (muscular endurance).

3. *Progressive overload:* As the body adapts to a given stimulus, an increase in the stimulus is

required for further adaptations and improvements. Thus, if the load or volume is not increased over time, progress will be limited.

4. *Variation in training:* No one program should be used without changing the exercise stimulus over time. Periodized training is the major concept related to the optimal training and recovery programming.

5. *Prioritization of training:* It is difficult to train for all aspects of strength fitness. Thus, within a periodized training program, one needs to focus or prioritize the training goals for each training cycle.

The Needs Analysis

A needs analysis of the individual should be performed to design the most effective program. The major questions in a needs analysis are as follows:

- What muscle groups need to be trained?
- What are the basic energy sources (e.g., anaerobic, aerobic) that need to be trained?
- What type of muscle action (e.g., isometric, eccentric actions) should be used?
- What are the primary sites of injury for the particular sport? What is the prior injury history of the individual?

Acute Program Variables

Developed more than 20 years ago, the paradigm of acute program variables allows one to define every workout. Every resistance exercise protocol or workout is derived from the five acute program variables. The choices made for each of the variables define the exercise stimuli and, ultimately with repeated exposure, the training adaptations.

1. *Choice of exercises:* Exercises can be divided into several different categories based on their function and/or muscle involvement. Exercises can be designated as primary exercises or assistance exercises. Primary exercises train the prime movers in a particular movement and are typically major muscle group exercises (e.g., leg press, bench press, hang pulls). Assistance exercises are exercises that train predominantly a single muscle group (e.g., triceps press, biceps curls) and those that aid (synergists) in the movement produced by the prime movers. Exercises can also be classified as multijoint or single-joint exercises. Multijoint exercises require the coordinated action of several muscle groups and joints. Multijoint exercises require neural coordination among muscles and, thus, promote coordinated multijoint and multi–muscle group movements. Power cleans, power snatches, deadlifts, and squats are good examples of whole-body multijoint exercises. The bench press, which involves movement of both elbow and shoulder joints, is also a multijoint, multi–muscle group exercise, although it only involves movement in the upper body. Some other examples of multijoint exercises are the lateral pull-down, military press, and squat. Incorporating multijoint exercises in a resistance training program is important for both athletes and nonathletes. Exercises that attempt to isolate a particular muscle group's movement of a single joint are known as single-joint and/or single–muscle group exercises. Biceps curls, knee extensions, and knee curls are examples of isolated single-joint, single–muscle group exercises. Many assistance exercises may be classified as single–muscle group or single-joint exercises.

2. *Order of exercises:* The order in which the chosen exercises are performed is an important variable that affects the quality and focus of the workout. In general, the sequence of exercises for both multiple– and single–muscle group exercise sessions should be as follows:

- Large–muscle group before small–muscle group exercises
- Multijoint before single-joint exercises
- Alternating of push/pull exercises for total-body sessions
- Alternating of upper/lower body exercises for total-body sessions
- Explosive/power-type lifts (i.e., Olympic lifts) before basic strength and single-joint exercises
- Exercises for weak areas (priority) performed before exercises for strong areas
- Most intense before least intense exercises (particularly when performing several exercises consecutively for the same muscle group)

3. *Resistance and repetitions used:* The amount of resistance used for a specific exercise is one of the key variables in any resistance training program. It is the major stimulus related to changes observed in measures of strength and local muscular endurance. Typically, a repetition maximum (RM) target range (i.e., 3–5 RM) is used to prevent muscular failure due to adverse changes in blood pressure and joint compression. Performing 3 to 5 repetitions with a resistance that allows for only 3 to 5 repetitions compared with a resistance that would allow 13 or 15 repetitions produces a heavier training intensity and greater strength changes. In some exercises, one cannot use an RM zone, so one uses a percentage of the 1 RM target (e.g., 70% or 85% of 1 RM). This method requires that the maximal strength in all exercises used in the training program be evaluated regularly. In some exercises, a percentage of 1 RM needs to be used as going to failure or near failure is not optimal (e.g., power cleans, Olympic-style lifts). Without regular 1 RM testing (e.g., each week), the percentage of 1 RM actually used during training, especially at the beginning of a program, will decrease, and the training intensity will be reduced. When possible, it is recommended that the RM target range be used as it allows the trainer to alter the resistance in response to changes in the number of repetitions that can be performed at a given absolute resistance. Specific neuromuscular adaptations to resistance training depend in large part on the resistance used. These adaptations follow the SAID principle described earlier in this entry. Heavier resistances will produce lower numbers of repetitions (1–6) but have been found to lead to greater improvements in maximal strength. Thus, if maximal strength is desired, heavier loads should be used. Alternately, if muscular endurance is the goal, a lower load should be used, which will in turn allow a greater number of repetitions (12–15) to be returned.

4. *Number of sets for each exercise:* First the number of sets does not have to be the same for all exercises in a workout program. In reality, apart from training mythologies, the number of sets performed for each exercise is one variable in what is referred to as the *volume* of exercise equation (e.g., sets × reps × resistance) calculation. As such, one of the major roles of the number of sets performed is to regulate the volume performed during a particular exercise protocol or training program. These findings prompted the 2002 recommendation from the ACSM for periodized multiple-set programs when long-term progression (not maintenance) is the goal. No study has shown single-set training to be superior to multiple-set training in either trained or untrained individuals. Exercise volume is a vital concept in resistance training progression, especially for those who have already achieved a basic level of training or strength fitness. As mentioned earlier, the principle of variation in training, or more specifically "periodized training," involves the number of sets performed. Since the use of a constant-volume program can lead to staleness and lack of adherence to training, variations in training volume (i.e., both low- and high-volume exercise protocols) is important during a long-term training program to provide adequate rest and recovery periods.

5. *Duration of rest period between sets and exercises:* The rest periods play an important role in dictating the metabolic stress of the workout and influence the amount of resistance that can be used during each set or exercise. A major reason for this is that the primary energy system used during resistance exercise, the ATP-creatine phosphate system, needs to be replenished, and this process takes time. Therefore, the duration of the rest period significantly influences the metabolic, hormonal, and cardiovascular responses to an acute bout of resistance exercise, as well as the performance of subsequent sets.

For advanced training emphasizing absolute strength or power (few repetitions and maximal or near-maximal resistance), rest periods of at least 3 to 5 minutes are recommended for large–muscle mass multijoint exercises (e.g., squat, power clean, or deadlift), whereas shorter rest periods may be sufficient for smaller–muscle mass exercises or single-joint movements. For a novice-to-intermediate resistance exercise protocol, rest periods of 2 to 3 minutes may suffice for large–muscle mass multijoint exercises, since the lower absolute resistance used at this training level seems to be less stressful to the neuromuscular system. Performance of maximal resistance exercises requires maximal energy substrate availability at the onset of the exercise and a minimum fatigue level and, thus, requires relatively long rest periods between sets and exercises.

The key to rest period lengths is the observation of symptoms of loss of force production in the beginning of the workout and clinical symptoms of nausea, dizziness, and fainting, which are direct signs of the inability to tolerate the workout. When such symptoms occur, the workout should be stopped, and longer rest periods should be used in subsequent workouts. With aging, a decreased ability to tolerate decreases in muscle and blood pH underscores the need for gradual progression when cutting rest period lengths between sets and exercises. Rest periods may be as follows:

Very short rest periods: 1 minute or shorter

Short rest periods: 1 to 2 minutes

Moderate rest periods: 2 to 3 minutes

Long rest periods: 3 to 4 minutes

Very long rest periods: 5 minutes or longer

Variation and Periodization of Resistance Training

Periodization involves the use of different types of workouts over time with different resistance intensities and volumes of exercise. Periodization also includes periods of rest to allow for recovery and prevent overtraining. Understanding the “size principle” is important as heavier loads with adequate volume recruit more muscle tissue and enhance strength more than lighter resistances. The use of the “size principle” is vital for understanding variation in resistance training and, ultimately, periodized training. (See *Designing Resistance Training Programs* by Fleck and Kraemer, 2004.) Typically, periodization is applied to large–muscle group exercises, with smaller variations from moderate to light for small–muscle group exercises.

Periodization of Exercise

The use of periodized resistance training has been shown to be superior to constant training methods (*Designing Resistance Training Programs*). Periodized training involves planned variation in the intensity of exercises and in the volume of a workout. Typically, one periodizes large–muscle group exercises. However, variation schemes can be created for smaller muscle groups. One must consider the type of periodized program to use. In general, there are two basic types that have developed. Below are some of the basic differences between linear and nonlinear periodization approaches to resistance training.

Classic Linear Models

Classic periodization methods use a progressive increase in intensity, with small variations in each 2- to 4-week microcycle. For example, a classic four-cycle linear periodized program (4 weeks for each cycle) would be as follows:

Linear Periodized Program

Microcycle 1: 3 to 5 sets of 12 to 15 RM

Microcycle 2: 4 to 5 sets of 8 to 10 RM

Microcycle 3: 3 to 4 sets of 4 to 6 RM

Microcycle 4: 3 to 5 sets of 1 to 3 RM

Rest and recovery cycle

You can see that there is some variation within each microcycle due to the repetition range of each cycle. Still, the general trend for the 16-week program is a steady linear increase in the resistance intensity of the training program. Due to the straight-line increase in the intensity of the program, it has been termed *linear* periodized training. The volume of the training program will also vary, with the classic program starting with a higher initial volume and the volume gradually decreasing as the intensity of the program increases. The drop-off between the intensity and volume of exercise can become less as the training status of the athlete advances. In other words, advanced athletes can tolerate higher volumes of exercise during the heavy and very heavy microcycles. It is very important to point out here that one must be very careful not to progress too quickly to train with high volumes of heavy weights.

The increase in the intensity of the periodized program then starts to develop the needed nervous system adaptations for enhanced motor unit recruitment. This happens as the program progresses and heavier resistances are used. Heavier weights demand high-threshold motor units to become involved in the force production process. With the associated increase in muscle protein in the muscles from the early cycle training, force production of the motor units is enhanced. Here again, one sees an integration of the different parts of the 16-week training program. A 16-week program in reality is called a mesocycle, and a 1-year training program (macrocycle) is made up of several mesocycles. Each mesocycle attempts to progress the body's muscle hypertrophy and strength upward toward one's theoretical genetic maximum.

Nonlinear Periodized Programs

More recently, the concept of nonlinear periodized training programs has been developed to maintain variation in the training stimulus. However, nonlinear periodized training makes implementation of the program possible due to schedule or competitive demands. The nonlinear program allows for variation in intensity and volume within each week over the course of the training program (e.g., 16 weeks). An example of a nonlinear periodized training program over a 16-week mesocycle is as follows:

Nonlinear Periodized Program

This protocol uses a 6-day rotation with 1-day rest between workouts.

Monday: 4 sets of 12 to 15 RM

Wednesday: 4 sets of 8 to 10 RM

Friday: 3 to 4 sets of 4 to 6 RM

Monday: 4 to 5 sets of 1 to 3 RM

Wednesday: Power Day, 4 to 6 sets of 2 to 3 repetitions with 30% to 45% of 1 RM

Friday: 2 sets of 12 to 15 RM

Rest days: Used as needed to replace a training day

The variation in training is much greater within the week. One can easily see that intensity spans a maximum of a 14-RM range (possible 1-RM sets vs. 15-RM sets in the week cycle). This span in training variation appears to be as effective as linear programs. One can also add a "power" training day, where loads may be from 30% to 45% of 1 RM and release of the mass is allowed if no deceleration exists with movement of the joint(s). Medicine ball plyometrics and other lower body plyometrics are also performed here as well.

Unlike the linear programs, one trains the different components of muscle size and strength within the same week. Unlike the linear methods, nonlinear programs attempt to train both the hypertrophy and the neural aspects of strength within the same week. Thus, one is working at two different physiological adaptations together within the same 7- to 10-day period of the 16-week mesocycle. This appears possible and may be more conducive to many individuals' schedules, especially when competitions, travel, or other schedule conflicts make the traditional linear method difficult to adhere to.

In this program, one just rotates through the different protocols. The workout rotates between very heavy, heavy, moderate, and light training sessions. If one misses the Monday workout, the rotation order is just pushed forward, meaning that one just performs the rotated workout scheduled. For example, if the light 12 to 15 workout was scheduled for Monday and you miss it, you just perform it on Wednesday and continue with the rotation sequence. In this way, no workout stimulus is missed in the training program. One can also say that a mesocycle will be completed when a certain number of workouts are completed (e.g., 48) and not use training weeks to set the program length.

Again, the primary exercises are typically periodized, but one can also use a two-cycle program to vary the small–muscle group exercises. For example, in the "triceps pushdown," one could rotate between the moderate (8–10 RM) and the heavy (4–6 RM) cycle intensities. This would provide not only the hypertrophy needed for such isolated muscles of a joint but also the strength to support heavier workouts of the large muscle groups.

Conclusion

In conclusion, two different approaches can be used to periodize your training program, more specifically, linear and nonlinear program schedules. The programs appear to accomplish the same effect and are superior to constant-training programs. It appears that this is accomplished by training the hypertrophy component first and then the neural strength component in the linear method and both components within a 7- to 10-day time period in the nonlinear method. The key to workout success is variation, and different approaches can be used over the year to accomplish this training need.

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See also Exercise During Pregnancy and Postpartum; Home Exercise Equipment; Mental Health Benefits of Sports and Exercise; Osteoporosis Prevention Through Exercise; Pediatric Obesity, Sports, and Exercise; Women's Health, Effects of Exercise on

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Exertional Compartment Syndrome, Chronic

Chronic exertional compartment syndrome (CECS) is a condition where exercising muscles swell within a confined space, resulting in decreased blood flow, pain, and limited activity. CECS is almost always seen in the lower leg but has been reported in the thigh, gluteus, and upper extremities. It is typically seen during the third or fourth decades of life but can also be seen in adolescents, particularly young female athletes. The patient generally presents with bilateral lower leg pain (often worse in one leg), which occurs with a consistent amount of vigorous exercise and resolves with rest. CECS has been reported in 15% of competitive runners and 5% of recreational runners. Surgical treatment is indicated in patients who have a confirmed diagnosis and have failed nonoperative treatment.

Anatomy

Extremity muscles are typically grouped together and surrounded by a strong, fibrous sheet of tissue called *fascia*. Muscular groupings surrounded by fascia are called *compartments*. In the lower leg, there are four compartments: (1) the anterior (front) compartment contains the tibialis anterior, extensor digitorum longus, and extensor hallucis longus muscles; (2) the lateral (outer lower leg) compartment contains the peroneus longus and brevis muscles; (3) the superficial posterior (superficial back of lower leg) compartment contains the gastrocnemius and soleus muscles; and (4) the deep posterior (deep back) compartment contains the tibialis posterior, flexor hallucis longus, and flexor digitorum longus muscles.

Causes

With exercise, muscles can increase in volume by 20%. When muscles swell within the confines of fascia, the pressure within the muscular compartment increases. The increased pressure, in turn, places pressure on the blood vessels flowing in and out of the muscles. When the pressure gets to a critical level, the blood flow to and from the muscles is decreased, reducing oxygen delivery and metabolite removal. In this situation, the muscles produce lactic acid and other metabolites that ultimately lead to nerve irritation and pain. The pain continues until activity is stopped, muscle swelling subsides, and blood flow is restored.

Patients who develop CECS are thought to have overly thick fascia, excessive muscle bulk, and/or abnormal blood flow regulation. CECS may also be caused by defects in the fascia. About 40% of patients with CECS have a fascial defect as compared with <5% of the general population. If there is a small tear or opening in the fascia, the muscle can herniate through the defect during exercise and cause pain secondary to strangulation of the herniated muscle tissue or by placing direct pressure on the surrounding nerves.

Symptoms

CECS presents as a dull ache localized to a lower leg muscle compartment, usually brought on by a consistent period of exercise and relieved by rest. The pain usually occurs in both legs, but is often more symptomatic in one, and causes the athlete to stop training or reduce exercise intensity. The anterior and lateral leg compartments are most commonly involved. Temporary numbness and/or tingling can occur in the sensory distribution of nerves in the affected compartment. Physical exam at rest is often normal. A firm compartment may be noted if the athlete is seen immediately after exercise.

Diagnosis

The diagnosis of CECS is made using a combination of clinical presentation and objective measurements. The evaluation starts with a complete history and physical exam. If there is suspicion of CECS, measuring compartment pressures can confirm the diagnosis. Compartment pressures are recorded both at rest and immediately after a period of exercise intense enough to cause symptoms. They are measured by a doctor using a special device. Most of the commercially available devices have a needle that is connected to a pressure transducer. The tip of the needle is inserted into each compartment, and the pressure transducer reports the pressure. A positive test occurs when resting pressures are >15 mmHg and/or postexercise pressures are >30 mmHg at 1 minute or >20 mmHg at 5 minutes postexercise.

Treatment

Conservative treatments include activity modification, massage, and physical therapy; however, these typically do not result in a cure, and symptoms generally return when the patient returns to his or her previous level of activity.

Surgery

Surgery is recommended for patients who meet the diagnostic criteria and for whom conservative treatment has failed. The goal of surgery is to reduce compartment pressures. This can be done by splitting the fascia, called a fasciotomy. After surgery, when the muscles swell with exercise, the pressure does not increase because the fascia is no longer a confining space. The surgery can be performed using an incision through the skin and the fascia (open technique) or through several small incisions using an arthroscope (endoscopic technique). Care must be taken when releasing the lateral compartment, so as to avoid damaging the superficial peroneal nerve.

After Surgery

Postoperatively, patients maintain a compression dressing, ice, and elevation for the first 3 days to limit swelling. They are made to weight bear as tolerated and may discontinue crutches when able. Gentle range of motion of the knees and ankles is encouraged. Physical therapy is not routinely employed early in the postoperative period as overly vigorous massage and activity can lead to scarring of the fascial compartments. Return to running is allowed at 6 to 8 weeks postoperatively. The use of accommodative orthotics is encouraged to maximize shock absorption by the foot, and the athlete should avoid running on hard surfaces during recovery.

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See also Athletic Shoe Selection; Compartment Syndrome, Anterior; Lower Leg Injuries

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Extensor Mechanism Injury

The extensor mechanism of the knee includes the quadriceps muscle group, the quadriceps femoris tendon, the patella, and the patellar tendon, which inserts onto the tibial tubercle. The quadriceps group and the patella allow for extension of the knee, which is required for a proper gait.

Functional Anatomy

The quadriceps muscle group receives its nerve supply from the femoral nerve. It consists of four muscles that insert onto the tibial tubercle. The vastus lateralis, vastus medialis, and vastus intermedius originate from the femur and cross the knee joint. The rectus femoris has two heads that originate from the ilium. It inserts into the patella through a strong central tendon and extends both hip and knee joints. These muscles envelop the patella and terminate to form the patellar tendon. During normal gait, there is compressive force on the posterior aspect of the patella equal to one half of the person's body weight. Jumping produces a force greater than eight times the body weight across this joint.

As the knee is flexed, complex biomechanics occur. When the patella glides on the distal femur, it has tilt, translation, and rotation. This produces a multiplanar toroidal path, like a bobsled going around a curve. When the knee is in complete extension, only the inferior part of the patella is in contact with the femoral condyle, and the patella can easily move from a medial to a lateral direction. As the knee flexes, the patella engages the femoral groove, and lateral movement is inhibited. As the knee goes from extension to flexion, a different aspect of the patella comes in contact with the femur.

As the knee flexes, the tibia internally rotates on the femur. This occurs because the femoral condyles are not equal in size. The medial femoral condyle is longer than the lateral femoral condyle, and as the menisci come in contact with the femur during knee flexion, it forces the tibia to rotate internally.

A number of structures affect patellar position relative to the femur and tibia. The lateral retinaculum of the knee is thicker and exerts more of a pull on the patella than the medial aspect of the retinaculum. Because of the double-headed origin of the rectus femoris, it exerts a superior lateral pull on the patella. The vastus medialis has a small distal portion described as the vastus medialis obliquus, which exerts a direct medial pull to the patella. This is an important muscle because it acts in concert with the articularis genu, a small muscle that inserts onto the medial superior synovial fold of the retinaculum, described as the plica. It is possible for this synovial fold, or plica, to impinge on the inner surface of the patella, affecting the articular cartilage during knee flexion. The articularis genu pulls the plica out of the way so it does not impinge, and the vastus medialis obliquus exerts its medial pull to keep the patella in the femoral groove.

Many textbooks describe the Q angle. The Q angle requires the measurement of a line connecting the anterior superior iliac spine through the midpatella, then measuring the angle it forms from the line connecting the midpatella to the tibial tuberosity. The normal female Q angle is up to 20°, with the male Q angle being 15°. It is critical to recognize that most authors do not feel that the Q angle is a predictor of anterior knee pain or subluxation of the patella, and it is inappropriate to make surgical decisions using this measurement. It is, however, a useful concept to understand the many forces that are exerted on the patella during knee flexion.

Physiology

The posterior aspect of the patella and the distal aspect of the femur are both coated with an articulate cartilage. Through the normal wear and tear of life, the articular cartilage is gradually worn away, and a fibrocartilage is laid down to replace it. It is not as functional as the former, but it is part of the reparative process of the body.

The term *chondromalacia* should be reserved for patients in which this condition has been arthroscopically diagnosed. The term *tendinitis* is often used to describe the pathophysiology of tendon injury and is inaccurate. This condition should be referred to as *tendinopathy* as there is no inflammation histologically.

Pathophysiology

The majority of patients have symptoms caused by overuse and are not surgical candidates. During examination, they will commonly hold the affected patella and describe the pain as more global. A few maneuvers can be useful in evaluating the cause of pain. The *patellar tilt test* is done with the patient in the supine position in complete knee extension. Downward pressure is applied to the medial edge of the patella. The test is positive if the angle is less than 15°, indicating an overly tight lateral retinaculum.

The *medial and lateral patellar glide test* is accomplished by pushing the patella in a medial and lateral direction with the patient in the position described above. The test is positive if the patella can be displaced more than 75% of its width.

The *grind test* is accomplished by instructing the patient to contract the quadriceps while the examiner compresses the patella against the femur in complete knee extension. A positive test occurs when the patient complains of pain, indicating chondral injury.

The *apprehension test* is performed with the knee in 30° of flexion. Lateral pressure is applied by the examiner. A positive test indicates patellar subluxation or dislocation if the patient is apprehensive and resists.

Often the exam result is negative, indicating that the knee is the "victim" of weak gluteal muscles, excessive foot pronation, genu valgus, or excessive anterior pelvic tilt causing "dynamic" impingement of the patella during activity.

Plica syndrome is a diagnosis that is made clinically, where X-ray and magnetic resonance imaging (MRI) findings will be normal. One of the synovial folds becomes fibrotic and rubs against the posterior aspect of the patella, causing chondromalacia during flexion and extension. The medial aspect of the plica is palpated and if a thick, inflamed fold is palpated, a diagnosis of plica syndrome should be considered.

Prepubescent patients often present with anterior knee pain that is localized to the tibial tubercle. This is a *traction apophysis* and is often caused by a rapid growth spurt. If prolonged discomfort occurs, a rare condition such as fracture of the tibial tuberosity should be considered. If the same condition occurs at the distal aspect of the patella, the condition is known as *Sinding-Larsen-Johansson disease*. These conditions are best treated by ice, anti-inflammatory medications, and modification of activities.

Ruptures of the quadriceps tendon usually occur in patients older than 40 years of age, and this is approximately three times more common than patellar tendon ruptures. Most ruptures occur approximately 2 centimeters superior to the patella and are often accompanied by the patient hearing a loud pop. The usual mechanism of injury is forced knee extension with resistance. Careful examination is required to diagnose an incomplete tear as there may be no palpable tendon defect. When one of the tears is suspected, imaging with either ultrasound or MRI should be done as soon as possible, as these injuries are best treated by early surgical intervention.

If a quadriceps muscle experiences a blunt trauma, a hematoma can form quickly. This should be diagnosed acutely, and the knee should be placed in as much flexion as tolerated by the patient for 24 to 48 hours. In addition to this, ice should be applied to the quadriceps. The use of heat should be discouraged. This injury can cause various sequelae, such as chronic anterior knee pain and myositis ossificans.

Patellar tendinopathy ("jumper's knee") usually affects the proximal attachment of the patellar tendon to the distal patellar pole and often occurs in patients who participate in jumping sports. Patients in their late teen years through the mid-30s usually develop this condition from microtrauma, but a single macrotraumic event may initiate this condition. Many times, these patients respond well to the use of ice, rest, and avoidance of the offending activity. In addition to this, strengthening the core abdominal muscles, strengthening the gluteal muscles, hamstring stretching, and isometric quadriceps exercises are useful. Some clinicians advocate various supports such as the Cho-Pat® strap or knee sleeves to change the angle of the patella on the proximal patella tendon. Surgical debridement is reserved for extreme cases. Patellar tendon rupture is much less common than quadriceps rupture.

In summary, most conditions of the extensor mechanism can be treated nonsurgically, and they are the result of extensor patellar tracking problems or biomechanics of the back, hip, and foot. Quadriceps and patella tendon ruptures are best diagnosed early and treated surgically.

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See also Knee Bracing; Knee Injuries; Knee Injuries, Surgery for; Musculoskeletal Tests, Knee

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Extracorporeal Shock Wave Therapy

Medical technology and devices are constantly changing. Newer and better techniques are being introduced in medical practice. One such advancement is *extracorporeal shock wave therapy* (ESWT) or *orthotripsy* for the treatment of various musculoskeletal disorders. It was developed, not so long ago, in the 1990s in Europe and is a derivative of lithotripsy (the mechanical breaking up of renal stones with sound waves).

ESWT is a noninvasive treatment that involves delivering low- or high-energy shock waves through a device to a specific site within the body. These pressure waves travel through fluid and the soft tissue parts of the body and cause their effects at sites where there is a change in impedance, such as the bone/soft tissue interface.

The use of ESWT in sports-related conditions is still controversial. However, this treatment is given after failure of traditional therapies and before resorting to surgery. In sports, it is used as a means to avoid surgery. A number of sportsmen have benefited from this therapy without requiring surgery. For example, during the Olympic Games in Sydney and Atlanta, the German athletes had the opportunity to be treated with this special therapy.

Types of Extracorporeal Shock Wave Therapy

Focal Shock Wave Therapy

Focal shock wave therapy is the more commonly used form of extracorporeal shock wave therapy. The shock waves generated outside the body are focused in the precisely defined therapy zone in the deeper tissue without harming the skin or superficial tissue. Focal shock wave therapy can be of low energy or high energy.

Low-Energy Shock Wave Therapy

Low-energy shock wave therapy is applied in a series of treatments, usually three or more. Low-energy shock waves cause mild or no pain.

High-Energy Shock Wave Therapy

The treatment is given in a single session. High-energy shock waves are quite painful, and some sort of anesthesia, either regional block or general anesthesia, is required.

The relative efficacy of the two types is different for treating different conditions. Conditions such as delayed unions and pathological calcifications are more responsive to higher-energy shock waves, while low-energy shock waves are safer and more effective for tendinopathies.

Radial Shock-Wave Therapy

Pressure waves are introduced over a large area of the skin, from where the waves spread divergently through the body tissues. This is also called unfocused shock wave therapy. However, it should be more accurately called radial pressure wave therapy since no true shock waves are generated.

Mechanism of Physiological Effects

The exact mechanism of the analgesic effects and effects on osseous defects of shock waves is not known; however, there are a couple of theories that attempt to explain the mechanism. According to the most accepted one, shock waves work by inducing microtrauma to the tissues. The microtrauma initiates a healing process by the body. This response causes neo-vascularization—that is, the formation of new blood vessels—resulting in improved blood flow into the area, which increases the delivery of nutrients in the affected area, thus promoting the repair process. The second opinion is that in cases of chronic pain, the body has stopped efforts to remove the cause of pain. The shock waves start a new inflammatory process, to which the body responds by providing nutrients to the area to promote healing.

Prerequisites for Treatment

To prevent improper treatment, there are certain prerequisites for administering the treatment:

- Correct clinical diagnosis is important (radiological examination, biochemical tests, etc., may be necessary).
- Only a qualified physician may use shock wave therapy.
- A high-energy focused shock wave therapy should be used for treating bone and deep tissue diseases.
- Devices with or without focusing technology may be used for superficial soft tissue conditions.
- The therapy should only be used after failure of the standard treatments for a given condition and when surgery is the only alternative.

Applications in Sports

ESWT has been successfully used in treating various sports-related injuries. Some of the most common conditions in which the therapy is beneficial are as follows:

Tennis elbow (lateral epicondylitis): It is commonly associated with playing tennis and other racquet sports; there is tenderness and soreness in the outer part of the elbow.

Golfer's elbow (medial epicondylitis): It is also sometimes called pitcher's elbow as it is associated with making a golf swing or throwing objects such as the ball in baseball. The insertion of the common tendon at the medial epicondyle becomes inflamed.

Rotator cuff (the group of muscles and their tendons that stabilize the shoulder) *injury with or without calcification:* This is due to the wear and tear or injury to the rotator cuff frequently sustained by athletes including baseball pitchers, American football quarterbacks, volleyball players, water polo players, shot put throwers, swimmers, boxers, fast bowlers in cricket, and tennis players.

Patella tendinitis (jumper's knee and Sinding-Larsen-Johansson disease) *with or without heel spur:* There is pain in the inferior patellar region. This injury is commonly encountered in football, rugby, volleyball, American football, basketball, and gymnastics.

Achilles tendinosis: The Achilles tendon is a tendon on the posterior aspect of the lower leg. It is commonly injured due to overuse in sports such as sprinting.

Plantar fasciitis: An inflammatory condition of the foot associated with walking for long periods, especially on hard surfaces. It is sometimes seen in runners.

Pseudoarthrosis or nonunions: It can occur after fractures.

Stress fracture: It is an incomplete fracture in bone due to repeated stress and is one of the most common injuries in sports. It has been reported to occur in almost all sports.

Contraindications

Contraindications to the procedure include neurological and vascular disease of the foot, a history of rupture of the plantar ligaments, open bone growth plates, pregnancy, implanted metal in the area, and medication that interferes with blood clotting, such as Coumadin and prophylactic aspirin. Because re-inflammation is being introduced, the patient should not take anti-inflammatory medication afterward.

Possible Complications

ESWT is generally considered a safe procedure, and not many complications have been reported. However, there is a possibility of recurrence on complications such as periosteum detachments, fractures of the inner surface of the cortex, compartment syndrome, neurological symptoms, and plantar fascial rupture. Relatively more potential complications are associated with high-energy than with low-energy therapy.

Conclusion

ESWT is not being used as a first-line treatment. Available literature is not sufficient to prove the long-term safety and efficacy of the treatment, and the available literature shows contrasting evidence. Moreover, proper treatment protocols have also not been established. Even though it is in its early phases of evolution, ESWT does show promise of becoming a standard treatment in sports medicine.

Anam Imtiaz and Muhammad Bilal

See also Achilles Tendinitis; Epicondylitis; Patellar Tendinitis; Plantar Fasciitis and Heel Spurs; Rotator Cuff Tendinopathy

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Extreme Sports, Injuries in

Extreme sports is a fluid, loosely defined term applied to a variety of typically nontraditional sporting endeavors. Other descriptive terms used for these sports include *action, adventure, alternative, millenial, next generation,* and *xtreme*.

The sports grouped under these terms are characterized to some degree by the following: a countercultural attitude, a relatively high degree of risk, and a high level of physical exertion or "action." They are typically "new" sports: Whereas boxing has been extant for millennia and basketball for over a century, snowboarding, for example, is only a few decades old. The extreme sports are also characterized by being frequently solitary endeavors. Evidence, furthermore, suggests that young athletes are increasingly turning away from more traditional sports in favor of nontraditional ones, including extreme sports, despite the fact that extreme sports are usually not sanctioned by schools. It is likely that the sports medicine professional will increasingly encounter participants of these extreme sports in his or her practice.

Overview

What sports are "extreme sports"? There is no single, authoritative definition of what constitutes this grouping. One classification made in 2004 by the author Joe Tomlinson in his book *Extreme Sports* divided extreme sports into those that take place in air, land, and water:

> *Air:* BASE (building, antennas, spans, and earth) jumping, bungee jumping, gliding, hang gliding, high wire, ski jumping, sky diving, sky surfing, and sky flying.

Land: Indoor climbing, adventure racing, aggressive inline skating, bicycle motocross (BMX), caving, extreme motocross (FMX), extreme skiing, freestyle skiing, land and ice yachting, mountain biking, mountain boarding, outdoor climbing, skateboarding, snowboarding, snowmobiling, speed biking, speed skiing, and street luge.

Water: Barefoot water skiing, cliff diving, free diving, jet skiing, open-water swimming, powerboat racing, round-the-world yacht racing, scuba diving, snorkeling, speed sailing, surfing, wakeboarding, whitewater kayaking, and windsurfing.

This list is meant to be instructive more than comprehensive. Some authors might not include some of these listed sports under the descriptor of "extreme sport" (e.g., power boating, yachting); others might include sports not listed above (e.g., ultraendurance events, ice climbing, sand dune skiing, parkour). Most of the sports that would fit in anyone's grouping of extreme sports, however, are not covered elsewhere in this text.

As noted earlier, a prototypical extreme sport would have the following attributes: a countercultural attitude, a relatively high degree of risk, and high levels of exertion or "action." Basketball, a traditional sport, arguably has a high level of risk (i.e., high injury rates) and is clearly marked by its action and physical intensity; however, it is a mainstream sport and is unlikely to be seen currently as "countercultural." Big-wave surfing, however, possesses all three attributes and is typically found on most lists of extreme sports.

Lest such classifications seem clear-cut, however, it should be noted that there is considerable debate over whether an activity such as bungee jumping, included in the listing above, would constitute an extreme sport: Though relatively risky and possibly countercultural, bungee jumping is an act that dissenters might argue lacks sufficient skill or physical ability on the practitioner's part to be classified as a "sport." Moreover, some have even questioned whether snowboarding, for example, now that it is an Olympic sport and "mainstream," could still be labeled an "extreme sport." Marathon running may have made the list of extreme sports at the beginning of the running boom, but with currently more than 50,000 people at the starting line of some marathons, it arguably is no longer "extreme." That distinction may be applicable only to ultramarathoning now.

Cultural Attributes

As has been noted already, there are cultural issues to be considered when reviewing the group of extreme sports, particularly as these issues affect sports medicine. For example, youths seem to be gravitating in larger numbers toward these sports. As it is well-known that musculoskeletal injuries in a skeletally immature athlete pose different challenges for the clinician, the phenomenon of youngsters pursuing these risky sporting endeavors has obvious medical implications.

This appeal of extreme sports to youth has not gone unrecognized by certain media and marketers. Though it might still be unusual to find an article on a surf competition in a local paper, some media outlets, such as ESPN, devote an increasing amount of their coverage to extreme sports. Indeed, ESPN, in hosting the "X Games," has been instrumental not only in developing extreme sports but also in broadening their appeal. Ironically, the very recognition that successful reporting and marketing brings to a sport can be the death knell of its "countercultural chic," what for many is the very essence of an extreme sport.

The nature of risk, and the apparent willingness of devotees of extreme sports to accept higher levels of risk, directly influences, of course, sports medicine's approach to these activities. Extreme sports devotees are sometimes called "adrenaline junkies," though out of scientific correctness, it should be pointed out that the neurotransmitter that is involved in reinforcement is dopamine and not adrenaline. Anecdotally, it appears that some extreme sports participants will seek new terrain or higher-risk versions of their sport in pursuit of the "extreme" ethic. There has been a general cultural evolution in these sports toward higher levels of risk. Marathons have evolved into ultramarathons, with the Marathon des Sables being a paragon: a 6-day, 150-mile endurance race run in the deserts of Morocco. Skateboarding, originally a street version of surfing, has evolved into aggressive skating, as epitomized in the documentary *Dogtown and Z-Boys: The Birth of Extreme*. Extreme surfers seek ever bigger waves, as epitomized by the Pipeline and Mavericks contests. Many sociological studies have been conducted on this quest by subsegments of certain sports to seek extreme levels of physical endurance and/or risk. For the purposes of this entry, it is mostly important to recognize the phenomenon and understand that over time, there will evolve newer, more "extreme" sports.

Injuries

Extreme sports are characterized by a variety of injuries and other sports medicine issues, but given the broad definition of the term, it is difficult to characterize these concerns. Moreover, there does not exist a large body of medical literature investigating the sports medicine aspects of extreme sports. The reasons for this dearth of information are related to many of the issues already discussed in this entry: the relative newness of the sports, the lack of mainstream recognition, and so on. Commentary on the injuries and illnesses seen in the group of extreme sports, then, is by necessity limited to a few medical studies, plenty of popular media stories, and a large number of anecdotes. The references at the end of the entry include some of the better studies existing in the current medical literature.

Some articles have begun to characterize the epidemiology of injuries and medical risks encountered by the extreme sports practitioner. Among the various injuries, there are the usual ones that occur in endeavors that put people at risk for falls, discussed elsewhere in this text. There are also a variety of injuries that are almost unique to individual sports, including scrotal injuries in mountain bikers, "snowboarder's ankle" (a fracture of the lateral process of the talus) in snowboarders, and a disruption of the A2 pulley of the finger seen in rock climbers and known as "climber's finger."

Data from New Zealand have been helpful in assessing some of the injury patterns in extreme, or adventure, sports. New Zealand is a mecca for participants in a wide variety of these sports, and the country's Accident Compensation Corporation (ACC) database is a rich source of epidemiologic data. One study from New Zealand calculated the morbidity and mortality rates for sports activity by visitors to the country. It found that 17% of all overseas visitor injuries and 22% of fatalities during a 15-year period were attributable to "adventure sports" activity. The injury incidence rate was calculated to be approximately 8 hospitalized injuries/100,000 overseas visitors (this may be compared with a rate of 12 hospitalized injuries/100,000 overseas visitors for motor vehicle accidents).

Protective equipment exists for many of these sports, from surfing to skateboarding to inline skating; anecdotally, there appear to be significant barriers (financial and aesthetic to name two) to participants actually using the equipment.

Extreme sports are also known as adventure sports for a reason: They can take place at times in unusual and taxing environments. Parasitic infections can affect athletes traveling to and competing in the developing world. Many of the water-based extreme sports can put participants at risk for marine envenomations and infections. Tick-borne diseases, such as Lyme disease and Rocky Mountain spotted fever, are a significant risk for athletes who participate in outdoor wilderness events. Sports medicine clinicians might be involved in event coverage or postcoverage treatment of individuals who are at risk; having knowledge of local, endemic medical risks is incumbent on these clinicians.

Finally, some of the extreme sports, such as the ultramarathons or adventure racing, require a good understanding of wilderness medicine, including an ability to recognize and manage thermal injury, dehydration, and altitude sickness, as well as the usual skills required for covering an urban mass sporting event.

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See also Mountain Bike Racing, Injuries in; Travel Medicine and the International Athlete

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Eye Injuries

As participation in sports and recreational activities has become increasingly popular, so have injuries associated with them become more common. According to the American Academy of Ophthalmology, sports are responsible for causing more than 40,000 eye injuries each year. More than 90% of sports-related eye injuries are preventable through the use of appropriate protective eyewear.

Overall, most eye injuries occur in basketball and baseball, followed by water sports and racquet sports. The severity of sports-induced injuries varies from mild scrapes of the cornea to severe trauma that may even lead to loss of vision. The majority of eye injuries occur in persons under 30 years of age. Children are especially vulnerable as they often lack depth perception and may misjudge the position, speed, and/or distance of a flying ball.

In cases of ocular injury, immediate evaluation by a physician is important to ensure preservation of vision; referral to an ophthalmologist for full evaluation should be made as soon as possible.

Anatomy

The *sclera* is the opaque (usually white), fibrous, protective, outermost layer of the eye. The front sixth of this layer, called the *cornea,* is transparent and covers the iris, pupil, and anterior chamber.

Inner to the sclera is the choroid, the front part of which contains three structures:

1. The *ciliary body* is the muscular area attached to the lens. It contracts and relaxes to control the size of the lens for focusing.
2. The *iris* is the sphincter that surrounds the pupil.
3. The *retina* is the light-sensitive tissue lining the innermost surface of the eye.

Light rays enter through the pupil and are focused on the retina after being refracted through the lens. Finally, the optic nerve carries the visual images to the brain (Figure 1).

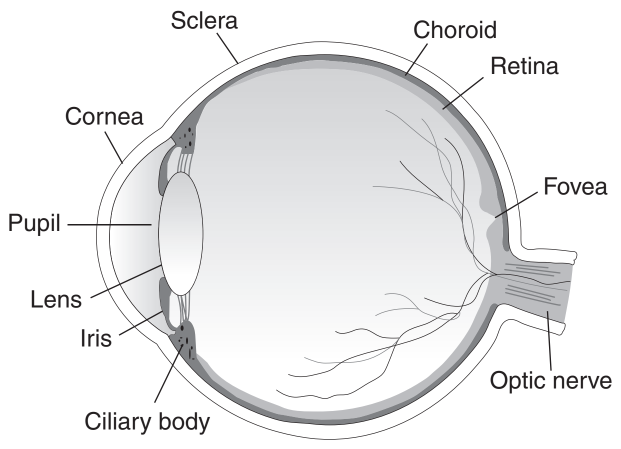

Figure 1 Sagittal Section of the Human Eye

Comparative Risk of Eye Injury, by Sport

Low Risk

There is no use of a ball, puck, bat, stick, or racquet in low-risk sports, and they do not involve body contact. Some low-risk sports are track-and-field, swimming, gymnastics, and cycling.

High Risk

A ball, puck, bat, stick, or racquet is used in high-risk sports, and they involve body contact. Examples of high-risk sports are baseball, basketball, hockey, football, lacrosse, tennis and other racquet sports, fencing, golf, and water polo.

Very High Risk

Very high risk sports involve body contact and do not use eye protectors. Some very high risk sports are boxing, wrestling, and contact martial arts.

Types of Sports-Related Eye Injuries

Types of eye trauma that can result from sports injuries include blunt trauma, corneal abrasions, penetrating trauma, and radiation injury.

Corneal Abrasion

Corneal abrasions are painful scratches on the cornea. They are not severe and eventually heal on their own. The most common cause of sports-related corneal abrasions is a scratch from a fingernail, a common event during a basketball game.

Blunt Trauma

The eye can be suddenly compressed by impact from an object, resulting in blunt injury. This is the most common form of sports-related eye injury. This can occur with player-to-player contact or when a ball or racquet strikes the eye. The severity of a blunt injury depends on the size, hardness, and velocity of the object. It can lead to a variety of injuries ranging from a black eye or hyphema (bruising of the eyelid), to a "blowout" fracture (fracture of the bone surrounding the eyeball), to a ruptured globe (rupture of the eyeball). The important structures inside the eye, such as the optic nerve, may also be damaged, resulting in permanent loss of vision.

Penetrating Injury

Penetrating injuries are relatively uncommon and occur when a foreign object pierces the eye. The object can be a BB from an air gun, a fish hook, a fingernail, or a fragment from shattered eyeglasses. Perforating BB gun injuries are the most serious type as these have the worst prognosis and often result in enucleation (removal of the eye, leaving the eye muscles and the remaining orbital contents intact).

Penetrating injuries range from mild abrasions to serious lacerations.

Radiation Injury

Radiation injury occurs as a result of exposure to UV radiation from the sun. Such an exposure is most common in sports such as snow skiing, water skiing, and other water sports.

Protective Measures

Wearing proper eye protection, although it cannot eliminate risk, greatly reduces the number and severity of ocular injuries.

Contact lenses and eyeglasses do not provide adequate protection. In fact lenses of regular eyeglasses can shatter on impact from a ball and can lead to a blunt or penetrating injury.

The American Society for Testing and Materials (ASTM) has recommended a certain type of protective eyewear for each sport.

Protective sports eyewear with polycarbonate lenses should be worn for basketball, racquet sports, soccer, and field hockey. Two-millimeter (mm) polycarbonate lenses in frames are for low-risk sports, and 3-mm lenses are recommended for moderate- to high-risk sports. Polycarbonate lenses are the thinnest and lightest lenses available. They are highly impact resistant and are available in prescription (for athletes with refractive errors) and plain forms.

Wearing goggles during a basketball game can protect against corneal abrasions. Safety goggles are also advised for children who play softball and baseball.

There is no satisfactory eye protection for boxing and full-contact martial arts, although thumbless gloves can greatly reduce the number of boxing eye injuries.

Total head and face protection is essential in collision sports; for example, a helmet with a polycarbonate face mask or wire shield should be used in football, hockey, baseball, and lacrosse.

Preparticipation Examination

A complete preparticipation eye examination of all athletes should be done. The physician should obtain the ocular history. Athletes with a high degree of myopia (near- or short-sightedness), eye surgery, injury, or infection are at increased risk.

Functionally One-Eyed Athletes

If the best corrected visual acuity in one of the eyes is less than 20/40, the athlete is considered monocular. ASTM has recommended special sports eye protectors for such persons. Eye protectors must be worn beneath a face mask in sports that require facial protection (i.e., hockey, football, and lacrosse).

An ophthalmologist should evaluate the monocular athlete before he or she is permitted to participate in a particular sport.

Warning Signs of Potentially Serious Eye Injury

- Visual loss or reduction
- Blurring of vision

- Pain on movement of the eye
- Tears in the outer ocular walls
- Presence of a foreign body inside the eye
- Bleeding on the surface or inside the eye
- Red and inflamed eye
- Photophobia
- Light flashes or floaters
- Suspected globe perforations

First Aid

Prompt first aid after eye injury greatly improves the chance of preserving vision. The recommended first aid involves a protective cover, such as taping the bottom of a paper cup over the eye or placing any other clean object there. The eye should be closed, to prevent involuntary movement of the injured eye. The athlete should be seen as soon as possible by an ophthalmologist for full evaluation of the injury.

In case of radiation injury, the victim should be removed from the source of UV light immediately.

Ocular Examination

An adequate history should be obtained to determine the force and direction of the impact. Best corrected visual acuity (clearness of vision), field of view, pupil sizes, full motility in all positions of gaze, and pupil constriction on exposure to direct light should be checked. A penlight examination of the anterior chamber should be performed to check for foreign bodies, hyphemia, abrasions, and lacerations. Occult rupture of the globe may be suspected if the red reflex (reddish-orange reflection from the eye's retina observed with an ophthalmoscope or retinoscope) is altered.

Prompt referral to an ophthalmologist is highly important in all cases as symptoms of severe injury are not always obvious.

Return to Sports

During the game, immediate return to play depends on the athlete's symptoms and the nature of the injury as determined by the team's physician. Following an eye injury and the athlete's removal from play, the athlete may return to play only after approval by an ophthalmologist.

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See also Head Injuries; Protective Equipment in Sports

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F

Facial Injuries

Because few sports mandate facial protection or mouth guards during sports participation, faces are generally exposed and therefore at risk of injury. Between 3% and 29% of facial injuries result from sports participation. Approximately 10% to 42% of facial fractures occur in sports. The majority of these injuries occur in males aged 10 to 29 years.

Injuries to the face in sport are usually caused by direct trauma. Impact can result from equipment (goalpost, stick, ball), another player (fist, elbow, head), the ground (gym floor, wrestling mat), or the environment (tree, wall). Direct trauma can result in injuries to any of the facial components, including the facial bones, nose, eyes, teeth, and ears. Injury patterns are sport specific and are common in hockey, soccer, baseball, boxing, rugby, and skiing. Up to 95% of professional hockey players sustain some type of facial injury throughout their career.

Eye injuries can be serious but are generally preventable. Eye injuries occur most often in stick sports, such as hockey or lacrosse; racquet sports, especially squash; sports involving a ball or projectile, such as baseball, football, and soccer; and contact sports, such as basketball. It is estimated that there are more than 40,000 eye injuries from sports annually in the United States, with the majority of injuries occurring in basketball, water sports, baseball, and racquet sports. Approximately 5% of college varsity athletes sustain some type of eye injury each season.

Injuries to the teeth resulting from sports participation are common. In the United States, one third of dental injuries occur in sports-related activities. The main types of trauma include tooth fracture, avulsion, luxation, and socket injury. Often, other maxillofacial injury is associated with dental trauma, so it is important to rule out other injuries when assessing an athlete with a dental injury. Dental injuries result from collisions with opponents or direct blows from equipment such as hockey sticks and bats.

Nasal injuries are quite common in contact sports such as boxing and football. Nasal fractures are the most common midfacial fractures in athletes. Injuries to the ears are relatively uncommon. The most common injury to the ear is an auricular hematoma, seen in sports such as wrestling and judo. Injuries to the facial bones result from contact with equipment or other players.

Anatomy

Most of the bones of the face are subcutaneous, which makes examination of the face fairly straightforward. The forehead is formed by the frontal bone of the skull. The eyes are enclosed by the orbits, which are cone-shaped cavities formed by the union of seven cranial and facial bones. The orbital margin comprises the supraorbital ridge, superiorly; the infraorbital ridge, inferiorly; the zygomatic arch, laterally; and the nasal bone, medially. The resulting cavity protects the eye from blows from large objects.

The zygomatic arch of the malar bone results in the prominence of the cheek. The upper jaw consists of the maxilla. The superior surface of the maxilla forms the floor of the orbit, while the inferior surface forms the majority of the hard palate. The horseshoe-shaped mandible forms the lower jaw. The mandible comprises the body, angle, and ramus. The coronoid process is inside the mouth. The gingiva or gums overlie the alveolar ridge.

The teeth are located in individual sockets within the maxillary and alveolar bone. Each tooth is composed of a root and crown. The tooth root is attached to the socket by periodontal ligaments and is covered by cementum. The root contains the vascular pulp, the nerve, and the blood supply of the tooth. The crown consists of a tough outer shell of enamel, which protects the inner layer of dentin and the pulp extending to the crown. The gingival tissue overlying the maxilla and mandible seals the tooth in the socket.

Evaluation of Injuries

Facial injuries should be assumed to be closed-head injuries. In an unconscious athlete, a neck injury should be assumed and the athlete should be appropriately immobilized by qualified personnel. A doctor, nurse, or paramedic should evaluate the athlete's airway, breathing, and circulation. The airway may be obstructed by blood, dislodged teeth, or dental appliances or by structural injury to the bony structures, such as the mandible. If there is any airway compromise, the athlete should be intubated by a trained doctor or paramedic. Breathing should be supported as needed. Facial injuries are frequently associated with profuse bleeding. If there is significant bleeding, intravenous access should be established by trained personnel and intravenous fluids should be administered. Any unconscious or unstable athlete should be rapidly transported on a spinal board to the nearest hospital.

Details of Injury

The mechanism of facial injuries is usually direct or indirect impact. The location of the athlete's pain can help determine the nature of the injury. With some injuries, the athlete may lose consciousness or have amnesia of the events surrounding the time of the injury. The athlete may have a headache, nausea, or difficulty concentrating. If there is a history of prolonged loss of consciousness (>1 minute), significant amnesia, or symptoms of headache, nausea, or difficulty concentrating, there may also be a head injury.

Physical Findings

Facial injuries may result in bruising or active bleeding, as well as areas of asymmetry or deformity. There may be bleeding from the nose, obstruction of the nostrils, or leakage of cerebrospinal fluid (rhinorrhea). The ears may be bruised and swollen (hematoma), or there may be leakage of cerebrospinal fluid (otorrhea). There may be lacerations in the mouth or broken or misplaced teeth. Missing teeth should be located to ensure that they have not been aspirated (inhaled).

With fractures of the facial bones, tenderness to palpation will help localize the bone that is injured. There may also be crepitus (a crunching sensation to palpation), numbness, or deformities. Eye movements may be decreased because of the injury, and vision may be affected (double vision, blurred vision). The athlete may be unable to fully open his or her jaw or may have pain with jaw movement.

Investigations

Any significant eye injury should be evaluated with a slit lamp and referred to an ophthalmologist immediately.

Any suspected fractures of the facial bones should be evaluated with an X-ray or a computed tomography (CT) scan.

Dental trauma should be referred to a dentist for further evaluation. If teeth have been avulsed (knocked out) and cannot be located, a chest X-ray should be performed to rule out aspiration of the teeth. Avulsed teeth should immediately be placed in milk or saline solution to protect them until they can be replaced. Alternatively, avulsed teeth can be replaced in the socket and held in place with gum until the athlete is seen by a dentist. Avulsed teeth must be replaced within 1 hour to maintain viability.

Type of Injury

Table 1 lists a few of the common and less common facial injuries.

Table I Facial Injuries

Body Part	*Common*	*Less Common*
Facial soft tissue	Contusion	
	Laceration	
Eye	Corneal abrasion	Hyphema
	Foreign body	Retinal hemorrhage
	Subconjunctival hemorrhage	Retinal detachment
	Eyelid laceration	Lens dislocation
		Orbital blow-out fracture
Ear	Auricular hematoma (cauliflower ear)	Laceration
		Perforated tympanic membrane
Nose	Fracture	Septal hematoma
	Epistaxis	Fracture of nasal septum
Teeth	Enamel chip fracture	Crown fracture
	Luxated tooth	
	Avulsed tooth	
Facial bones	Temporomandibular joint sprain/malalignment	Fractured maxilla
		Fractured mandible

Prevention of Injury

Facial injuries can be prevented by wearing the appropriate protective equipment required by the sport or activity. Properly designed helmets, with appropriate facial protection, have reduced the incidence of facial injuries. In sports such as football, hockey, and lacrosse, protective helmets and face guards provide eye protection as well. Equipment must be properly maintained and replaced as necessary (e.g., single-impact helmets).

Protective eyewear should be worn in any sport where the risk of eye injury is high, such as squash and racquetball. Sport-appropriate eye protectors have been shown to reduce the risk of significant eye injury by 90%. Regular glasses and contact lenses do not protect the eyes from injury. Hard contact lenses should not be worn during sports activities. For most sports, 3-millimeter-thick polycarbonate lenses offer the best protection. Lenses should be treated to resist fog and should be fitted by an experienced ophthalmologist, optometrist, or optician.

An effective mouthguard can prevent or reduce the severity of dental injuries. Mouthguards should be custom-made and fitted by a dentist, kept in a plastic box, and rinsed regularly with an antiseptic mouthwash. They should be worn in collision sports, such as basketball, baseball, and soccer, as well as in contact sports, such as football, hockey, rugby, and wrestling.

Athletes participating in water sports, such as swimming and water polo, should use custom-fabricated ear plugs to maintain a dry ear canal. In athletes who experience repeated episodes of otitis externa, installation of alcohol ear drops (5% acetic acid in isopropyl alcohol) after each swimming episode may help prevent recurrence of infection.

Return to Sports

Most minor facial injuries do not interfere with sports participation. However, certain eye conditions preclude participation in contact sports. These conditions include having only one functional eye, severe myopia, Marfan syndrome, and previous retinal detachment. Some eye injuries, such as a hyphema (blood in the eye), require bed rest for several days. For any eye injury, the eye should be painfree and have adequate recovery of vision prior to resumption of sport.

Any facial injury requiring surgery requires appropriate recovery time prior to return to sport. Appropriate facial safety equipment should be worn on return to sport.

Laura Purcell

See also Dental Injuries; Head Injuries

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Family Doctor

The family doctor, formerly referred to as the *general practitioner,* has the unique role of caring for patients of both sexes over their entire life span, from the cradle to the grave. As a generalist, the family doctor comes equipped with a broad medical knowledge base and skill set that grants him or her the tools to provide comprehensive medical care, both acute and chronic. Included among these tools is training in preventive care, pediatrics, geriatrics, psychiatry, and the nonsurgical treatment of musculoskeletal injury. The possession of this training background helps explain why the family doctor is well suited to care for the athlete well beyond primary treatment of acute injury, in the distinctive role of comprehensive care sports medicine physician.

Defining the Family Physician

To best understand why the modern family doctor is well positioned to care for the athlete, it is helpful to first examine the official definition of family physician. The American Academy of Family Physicians (AAFP) defines *family physician* as

> a physician who is educated and trained in family medicine—a broadly encompassing medical specialty. Family physicians possess unique attitudes, skills, and knowledge, which qualify them to provide continuing and comprehensive medical care, health maintenance and preventive services to each member of the family regardless of sex, age, or type of problem, be it biological, behavioral, or social. These specialists, because of their background and interactions with the family, are best qualified to serve as each patient's advocate in all health-related matters, including the appropriate use of consultants, health services, and community resources.

Simply translated, the family doctor is trained to care for the whole person throughout his or her life, both physically and emotionally, in the context of the patient's medical history, family dynamics, and social standing in the community.

Further defined, the family doctor has a primary role as the patient's health care coordinator. This role begins with the first contact, when the physician is in a unique position to form a bond with the patient. Thereafter, in the event that a medical condition is beyond the treatment capabilities of the family doctor, he or she will function as the patient's means of entry into the health care system through referral to the appropriate specialist. Beyond this action, the family doctor continues as the health care coordinator in an effort to prevent fragmentation of care along the continuum. Acting on the desire to always optimize patient health, the family doctor serves a vital role as the patient's advocate in dealing with other entities including insurance companies, employers, teachers, and, in the patient who is an athlete, coaches and trainers.

Family doctors are often referred to as primary care physicians. It is important to understand, however, that while "primary care" encompasses the type of services most often provided by family doctors, the terms *primary care* and *family medicine* are not interchangeable. In light of the preceding description and the discussion to follow, it will become evident that "primary care" is but one of the services provided by family doctors.

Comprehensive Care of the Athlete: An Illustration

As an example designed to illustrate the unique role the family doctor serves in providing comprehensive, multidimensional care to the athlete, consider the following scenario.

Patient *X* is a high school senior and captain of the football team. A star linebacker, *X* has sustained three concussions to date, the last of which had occurred midseason in the junior year and was severe enough to ultimately end his season. His family doctor, Dr. *S,* possesses additional training in sports medicine and concussion management and has a mutually respectful relationship with the team physician. Dr. *S* was the initial examiner after all *X*'s concussions, coordinating emergency diagnostics and arranging office follow-up in each case. Trusted implicitly by *A*'s parents, who are also his patients, Dr. *S* applied the latest standard in concussion care, including adherence to strict return-to-play guidelines. When Dr. *S* informed *X*'s coach last season that *X* should sit out or risk serious sequelae in the event of a repeat concussion, the coach stated that he must have his star player back in the lineup to better their chances of getting to the play-offs. Acting in the interest of his patient's health and well-being, Dr. *S* refused to grant return-to-play, which in turn led to the coach's insistence on a second opinion. Dr. *S,* knowing both that the coach would request referral to the local neurologist and that this neurologist did not embrace neurocognitive testing, which is an inherent part of current evidence-based concussion care standards, advised *X*'s parents against the referral. At the same time, readily acknowledging his limitations and that he was not a brain injury expert, Dr. *S* suggested a neurologist from another hospital whom he knew to be up on concussion care standards. Dr. *S,* who also serves as the school health adviser, arranged education sessions on concussion for all athletic staff, parents, and students while also ensuring that all district high schools had neurocognitive testing capabilities.

Subsequent to the junior year concussion, *X* endured significant academic difficulties, prompting Dr. *S* to talk with his teachers, advocating on his behalf for necessary classroom accommodations. Among the postconcussion symptoms demonstrated by *X* were difficulty concentrating, chronic headache, insomnia, and severe depression. Despite good compliance with the indicated medications, *X* turned to drugs and alcohol in an effort to "better cope" with his distressing circumstances. The situation became even bleaker after it was determined through further evaluation just prior to the start of the senior year that *X* still exhibited significant cognitive deficits. Playing football again would prove very risky, and Dr. *S* advised against it. *X,* who not long before was being recruited by Division 1 football teams, began expressing suicidal thoughts, prompting Dr. *S* to arrange inpatient psychiatric care.

X overcame the crisis and has since established regular care with a therapist. Dr. *S* sat with *X* and his parents and had a frank discussion about his future. He made it a point to discuss the way concussion and its sequelae can profoundly affect every aspect of an individual's conscious existence. Dr. *S* encouraged *X* and his family to discuss the situation with their pastor, and he referred them to a psychologist as well as directing them to community support groups and online traumatic brain injury resources. Dr. *S* continued to see *X* regularly, following his concussion to resolution. *X*'s insurance company initially refused to pay for much of the concussion care but overturned their decision following a comprehensive letter from Dr. *S*.

Vital Functions

Among the many key points of this illustration, two stand out: (1) the family doctor's indispensable role as "comprehensive care coordinator" and (2) the realization that athletic injury, when significant, may have consequences well beyond mere tissue trauma. The family doctor is eminently equipped to both recognize and manage these consequences. The process begins with the initial patient contact, which in the case of the athlete is typically the preparticipation exam (PPE). Beyond the requisite physical information gained during a PPE, a well-trained family doctor determines the psychosocial setting in which the patient exists. For example, understanding the patient's family dynamics, support system, and academic ability may prove helpful during subsequent visits in understanding what contributes to disease states above and beyond acute musculoskeletal injury.

At the core of family medicine, and a key component of comprehensive care of the athlete, is health promotion and injury/illness prevention. These practices are driven by the family doctor's sworn duty to optimize health status while simultaneously minimizing injury risk. Apart from instruction in proper conditioning and safe exercise practices, general health promotion/preventive care measures include exercise prescription, nutrition counseling, screening for mental illness, and risk factor management. The latter practice generally refers to the identification and management of those factors that contribute to the development of coronary artery disease. In the case of the young athlete having a PPE, the family doctor strives to identify risky health behaviors over a broad spectrum of categories. These include drug, alcohol, and tobacco abuse; high-risk sexual practices; pathogenic weight control behaviors; and use of performance enhancement drugs. It becomes important for physician and athlete to work together in not allowing the focus to fall exclusively on acute issues surrounding a specific sport at the cost of losing sight of these preventive care measures.

Finally, looking beyond care of the school-age athlete, the family doctor is exceptionally well equipped to manage the vast array of general medical problems found in athletes of any age or sex, ranging from diabetes to exercise-induced asthma to headache. Likewise, the family doctor is prepared to diagnose and treat the medical problems of athletes in "special" populations. For example, in the mature athlete an understanding of the physiologic changes of aging is important when adjusting an exercise prescription. Among female athletes, counseling the pregnant athlete or treating the female triad poses another challenge for which the family doctor is well prepared. Knowledge may be further enhanced through the option of fellowship training in sports medicine available to doctors in any branch of primary care medicine but most often pursued by the family doctor.

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See also Careers in Sports Medicine; Preparticipation Cardiovascular Screening; Running a Sports Medicine Practice; Team Physician

Websites

American Academy of Family Physicians: http://www.aafp.org

Fat in the Athlete's Diet

Fat is an important energy substrate for athletes. It provides 9 kilocalories of energy per gram (kcal/g). It is body fuel for low-intensity, longer-duration exercise. About half of the total energy expenditure is derived from free fatty acid metabolism in moderate-intensity, long-duration exercise greater than 1 hour in length. Fat may contribute as much as 75% of the energy demand during prolonged aerobic work in the endurance-trained athlete. Fat is also essential for the absorption of certain vitamins. The most important role of dietary fat is to spare the use of carbohydrates during low-intensity, longer-duration exercise. In general, the true role of fats in exercise has not been well studied and is not well understood; therefore, further research is necessary.

Dietary Content

A diet with inadequate fat content can decrease muscle mass from lowered serum testosterone levels. Conversely, a diet high in fat can cause gastrointestinal discomfort before or during exercise as well as increasing fat stores despite exercise. Over time, too much fat can lead to heart disease, obesity, cancer, and other health problems. Fat intake for athletes, as well as healthy adults and children, should make up less than 30% of the total calories ingested. Fats in the diet may be of animal or vegetable origin. Selecting lean meats and nonfat or low-fat dairy products and limiting added fats such as butter, margarine, salad dressing, cream sauces, gravies, and fried foods will help achieve this goal.

Trained athletes use fat for energy more efficiently than untrained athletes because of their higher fat oxidative capacity due to increased enzyme levels, fatty acid transport, and beta oxidation, which spares the use of glycogen during endurance sports. Therefore, even endurance athletes generally do not require excess fat in the diet because they are metabolically more efficient. Even lean athletes generally have sufficient endogenous body fat stores to meet the metabolic demands of endurance and strenuous exercise. Consuming fat in a precompetition meal 2 hours or less before exercise should be generally avoided. There is evidence that the rate of fat metabolism may be accelerated by ingesting caffeine prior to and during endurance performance.

Types of Dietary Fat

Saturated fats are found primarily in animal sources such as meat, egg yolks, yogurt, cheese, butter, and milk. This type of fat is characterized by being solid at room temperature. Health problems such as heart disease, high cholesterol, and obesity have been linked to excessive dietary intake of saturated fats. Because of this, saturated fat should be limited to no more than 10% of total daily calorie intake.

Unsaturated fats include monounsaturated and polyunsaturated fats, which are typically found in plant food sources. This type of fat is characterized by being liquid at room temperature. Unsaturated fats have health benefits such as lowering cholesterol and reducing the risk of heart disease. Common food sources include olive and canola oil, fish, nuts, avocados, soybeans, and flaxseed.

Trans fats are created (naturally or artificially) when an unsaturated fat is made into a solid. Consumption of trans fats, like saturated fat, should be limited because they increase cholesterol levels and the risk of heart disease. The product content of trans fats has recently been added to many products' nutrition labels, thus allowing the consumer to make better dietary choices with regard to fat intake (Table 1).

Weight Loss

If an athlete desires to lose weight, it is reasonable to make sure that there is a reasonably low intake of dietary fat. If there is too much fat in the diet, then lowering fat intake may be beneficial in weight loss as the overall caloric intake will decrease readily. However, for athletes who pursue or achieve rapid weight loss, frequently this reflects mostly fluid weight loss despite dietary restriction of fat. Rapid weight loss issues are often found in weight class sports such as wrestling. Concerns about fluid weight loss include increased risks of dehydration and heat illness. Truly rapid fat weight loss is usually only achieved through excessive caloric restriction, which also can have negative consequences on an athlete's health and sports performance. Weight loss that will effectively decrease total body fat in an athlete must be achieved over time and with careful attention to overall dietary habits.

Weight Gain

There are some athletes who desire weight gain, usually those who would benefit from being stronger to compete in their sport or who need to gain weight to meet a desired weight class requirement. Usually, the desired weight gain is associated with gains in lean body mass, not fat mass, although this can be challenging. Gains in lean body mass can be advantageous for sports as improvements in strength and power are achieved. Gaining muscle weight can affect the body's resting metabolic rate and may adversely affect endurance performance. Gains in fat mass are universally unhelpful for an athlete. Fat mass decreases strength-to-weight ratios and does not improve strength or power. Agility performance, jump height, and endurance performance can also be adversely affected.

Some suggested techniques for gaining weight that emphasize a gain in lean body mass include the following: eat a healthy breakfast, eat frequently (every 2–3 hours), eat high-density foods such as dried fruits and cereals, and drink or cook with milk regularly. A gain of approximately 1.5% of total body weight per week is ideal. Add moderate- to high-intensity resistance exercise workouts 2 to 3 days a week. Make sure that there is adequate protein in the diet (1.5–1.8 g protein per kilogram

Table 1 Getting to Know Your Fats

	Properties	*Effects on Blood Cholesterol*	*Food Sources*
Saturated Fats	• Solids at room temperature • High melting point • Less likely to become rancid	• Increased harmful LDL cholesterol • Increased total cholesterol	• Animal sources—butter, whole milk, cream, cheese, ice cream, and other full fat dairy products; animal meats, lard, poultry skin • Plant sources—coconut oil, palm oils, cocoa butter • Trans fats are created when unsaturated fats are saturated through the process of hydrogenation—stick margarine, shortening, hydrogenated oils
Monounsaturated Fats	• Soft or liquid at room temperature • Lower melting points than saturated fats • May become rancid when exposed to light and oxygen for extended periods of time	• Decreased harmful LDL cholesterol • Minimal change in beneficial HDL cholesterol • Decreased total cholesterol	*(Plants)* • Olive, canola and peanut oils • Olives, peanut butter, nuts • Avocados
Polyunsaturated Fats	• Soft or liquid at room temperature • Lower melting points than saturated fats • May become rancid when exposed to light and oxygen for extended periods of time	• Decreased harmful LDL cholesterol • May decreased beneficial HDL cholesterol • Decreased total cholesterol	*(Types)* • Omega-6 ○ Linolenic acid—vegetable oils (corn, sunflower, safflower, soybean, cottonseed), poultry fat ○ Arachidonic acid—meats (or made from linoleic acid) • Omega-3 ○ Linolenic acid – Oils (flaxseed, canola, walnut, wheat germ, soybean) – Nuts and seeds (butternuts, walnuts, soybean kernels) – Vegetables (soybeans) ○ EPA and DHA—related to the prevention and treatment of heart disease, high blood pressure, arthritis and cancer – Human milk – Shellfish and fish (mackerel, salmon, anchovy, herring, lake trout, sardines, tuna) – Made in the body from linolenic acid

body weight per day). Genetic factors, sex, physiologic maturity, and endogenous anabolic hormone production all affect an athlete's ability to effectively gain lean body mass. Interestingly, children and adolescents generally have higher levels of glycerol in their blood, which results in increased use of free fatty acids during exercise.

Conclusion

Further research and education is needed to fully understand the role of fat in an athlete's diet. At present, it is important to educate athletes with regard to dietary needs, metabolism of fat, and healthy food choices. For those athletes who require additional calories to maintain a healthy energy balance, it is recommended that those calories come from increases primarily in carbohydrates in their diet and less from protein. It is also essential for athletes to maintain adequate fat (approximately 30%) in their diet to maintain overall health and well-being and optimize sports performance.

Holly J. Benjamin

See also Calcium in the Athlete's Diet; Carbohydrates in the Athlete's Diet; Dietary Supplements and Vitamins; Postgame Meal; Pregame Meal; Protein in the Athlete's Diet; Salt in the Athlete's Diet; Sports Drinks; Vegetarianism and Exercise; Weight Gain for Sports; Weight Loss for Sports

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Female Athlete

Women have made important advancements in sports and athletics over the past half-century. While females did participate in some sporting events, it was not until 1972, with the passing of Title IX of the Educational Assistance Act, that girls and young women in the United States became a strong force in the sports and health fitness arena. In the 2008 Beijing Olympics, more than 42% of the 11,028 participants were women. The International Olympic Committee expects this number to continue to rise. From young girls playing on recreational teams to women's professional leagues, females have proven themselves as capable athletes.

Female participation in athletic activities promotes exercise and a healthy lifestyle, with benefits that extend beyond the playing field. For women, playing sports leads to higher self-esteem, a positive body image, higher rates of both high school and college graduation, decreased drug use, and decreased sexual risk-taking behavior. While the female athlete has shown that she can be an equal competitor to her male counterpart, there are some sports medicine concerns unique to women and girls.

Females do differ from males in skeletal structure, body composition, physiology, and training effects. These differences lead to unique health and injury concerns for the female athlete. Skeletally, males and females are similar until adolescence, when girls begin their growth spurt an average of 2 years earlier than boys. As males and females reach their full height potential, bony differences are apparent between the sexes. These differences include females being smaller and shorter, with a lower peak bone mass, a wider pelvis, femurs that slant inward toward the knees, less bowing in the lower leg, narrower shoulders with more slope, and a wider "carrying angle" of the elbows. The differences in body composition include higher body fat percentage, lower lean body mass, and greater concentration of subcutaneous fat tissue, particularly in the hip and thigh area, in females than in males. Physiologically, women tend to have lower blood volume, less hemoglobin, a smaller heart, lower maximum cardiac output, a smaller thorax, less lung tissue, and less muscle mass, which all effectively lead to increased workload of the cardiovascular and pulmonary systems to perform the same level of exercise as their male counterparts. This can lead to differences in training effects, since women tend to lag behind men in endurance sports performance and tend to be weaker secondary to less muscle mass.

While the injury profile in males and females tends to be similar for acute injuries (fractures, dislocations, contusions, etc.), overuse injuries seem to be more commonly seen in female athletes. Often these types of injuries occur as a result of a lack of conditioning prior to participation in sports. From a young age, females are often less active than males, and when they do start sports activities, it is often at the height of their growth spurt (between ages 11 and 13). For this reason, it is important that females enter sports gradually and with proper conditioning if they have not been particularly active in their younger years (see the entry Strength Training for the Female Athlete).

Two overuse injuries that are commonly seen in females are stress fractures and patellofemoral pain syndrome. Stress fractures are the result of repetitive trauma to the bone causing a series of microfractures. Stress fractures commonly occur in places where bones are more susceptible to repetitive trauma, such as the tibias and feet of runners. While athletes of any skill level may develop stress fractures, they commonly occur in those who have suddenly increased the frequency or intensity of their training. Females are more commonly affected than males due to the hormonal influences of estrogen on bone. Estrogen helps stimulate the hormones that promote bone formation. Therefore, women who are not menstruating regularly may be at increased risk for stress fractures. (For more on the relationship between menstrual irregularities and stress fractures, refer to the entry Female Athlete Triad.)

Patellofemoral pain syndrome is about three times more common in females than in males. Symptoms of this include pain around the patella (kneecap) while walking or climbing stairs and increased pain or stiffness in the knees after periods of prolonged sitting. While no single biomechanical risk factor has been shown to be associated with this pain, there are a number of factors that might contribute to it. Muscle-tendon imbalances across the knee, such as tightness on the lateral thigh (iliotibial band) and weakness on the medial thigh (vastus medialis muscle), may cause the patella to shift with exercise. In addition, women often have a wider pelvis, which can increase the Q angle (the angle at which the femur meets the tibia), causing increased strain on the patellar tendon. Other factors such as inward rotation of the femurs, overly flat or arched feet with pronation while walking or running, and joint laxity can all contribute to this pain. For female athletes who may be predisposed to this condition, it is especially important to maintain proper strength and flexibility to prevent it.

One acute injury that occurs more often in women is a tear of the anterior cruciate ligament (ACL). This is due to a number of factors, including landing dynamics, training insufficiencies, increased laxity with possible hormonal influences, and anatomic differences. ACL injuries are often the result of either a straight knee landing or a sharp change in direction when the foot is planted. Female soccer players are twice as likely to sustain an ACL injury as male soccer players, and female basketball players are as much as five times more likely to sustain an ACL injury as male players.

Females seem to be more susceptible to ACL injuries for a few reasons. Females have less knee and hip flexion with landing, which places more body weight forward and the knee in a more angulated position. Additionally, women often have insufficient conditioning in the stabilizing muscles around the knee, with increased reliance on the ACL and less on the hamstring secondary to quadriceps dominance. While the literature views are mixed on the subject, some research suggests that there is also a hormonal component to ACL injuries, with increased laxity in the ovulatory phase of menstruation leading to an increased risk of injury. Furthermore, female ACLs tend to be smaller in length, cross-sectional area, volume, and mass, which makes them less likely to handle major increases in load.

Prevention programs have focused on increasing the ratio of hamstring to quadriceps strength through traditional stretching and strengthening, incorporating more agility and balance training in workouts, and using plyometrics to enhance joint stability and decrease landing force. Prospective outcome studies of such interventions are under way. It is hoped that as understanding about the causes and prevention of ACL injuries improves, the rates of ACL injuries in females will decrease.

In addition to inherent differences in build and injury profile, hormonal changes with menstruation may affect female athletes. The effect of the menstrual cycle on performance is highly individual. Approximately one third of all female athletes believe that the timing of their menses do affect their performance. However, Olympic gold medals have been won in all phases of the menstrual cycle. (See the entry Menstrual Cycle and Sports Performance.)

Another unique concern in female athletes is the relationship between exercise and pregnancy. Increases in maternal plasma volume that lead to mild anemia, amplification of maternal gas exchange in the fetus, and increased risk of falls due to increased joint laxity and a changed center of gravity all contribute to the importance of modifying activity for the sake of the woman's and baby's health. Women can often exercise safely throughout their pregnancy, as long as they are aware of the warning signs for ceasing activity and do not have any absolute contraindications. Regular aerobic exercising is good for muscle tone, control of body weight, and general well-being throughout pregnancy. In addition, regular moderate activity has no known significant outcome on birth weight or the time of delivery. (See the entry Exercise During Pregnancy and Postpartum.)

Female athletes have come a long way in the sports arena. There are unique considerations for female sports participation and the health of the female athlete. But as girls begin sports activity at an earlier age, with improved conditioning and technique, it is hoped that they will continue to break performance barriers and records while suffering from fewer injuries. We continue to become more knowledgeable about conditions unique to the female athlete, which will only enhance her success.

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See also Exercise During Pregnancy and Postpartum; Female Athlete Triad; Menstrual Cycle and Sports Performance; Strength Training for the Female Athlete; Title IX, Education Amendments of 1972

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Female Athlete Triad

Since the passage of Title IX in 1972, female participation in high school athletics has increased by 800%. While such participation has had a remarkably positive impact on girls, women, and sports, some pressures of athletics and training have placed athletic females at risk for overtraining, undereating, menstrual irregularity, low bone mass, and other adverse health consequences. In 1993, the American College of Sports Medicine coined a term, the *female athlete triad* (triad), to refer to a syndrome commonly seen in athletic women. It involves disordered eating, irregular menstrual cycles, and low bone mass. Athletic women with the most extreme form of this disorder have severe eating disorders (e.g., anorexia or bulimia), amenorrhea (absence of menstrual periods), and osteoporosis (low bone density with increased risk of fractures). However, the syndrome is a continuum, and athletes may have one, two, or all three parts of the triad.

Prevalence

Prevalence of the triad in a population of young women athletes is difficult to ascertain as most statistics are obtained from surveys and self-reporting. Women may not want to admit that they have menstrual irregularities or eating disorders. Underreporting is common in such surveys.

The prevalence of amenorrhea in the general population is 3% to 6%. In specific female athlete populations, amenorrhea has ranged from 3.4% to 69%. The prevalence of disordered eating is 5.5% to 9% in the general population, while surveys have shown a prevalence of 15% to 62% in female college athletes and 25% to 31% in female elite athletes.

Disordered Eating

Female athletes may try to lose weight or maintain a low body weight to improve their athletic performance. For example, a runner may try to lose weight to enhance her speed. A dancer may strive to be thin to improve her jumps and to achieve a certain ideal appearance on stage. Athletes are pressured by coaches, teammates, parents, and/or friends to lose a "few extra pounds" to enhance their performance. This can lead to poor body image and unhealthy eating behaviors.

Disordered eating as part of the triad includes restricting the intake of calories and/or certain types of food (e.g., fat). Some athletes have unintentional nutritional deficits because the calories burned during exercise consistently exceed the calories ingested, but the athlete is not aware of this imbalance. In other instances, athletes engage in very distinctive behaviors signifying the severe eating disorders, anorexia nervosa or bulimia nervosa. Athletes may fast, use diet pills, use laxatives or enemas, purge, try fatfree dieting, or even try excessive sweating through layering clothes in hot weather or sitting in saunas. At-risk athletes include those who restrict dietary intake, exercise for prolonged periods of time, or are vegetarian. Regardless of the type of disordered eating or weight control behavior, the nutritional deficit disrupts many hormonal processes in the body.

Amenorrhea

Rapid changes in weight, loss of specific nutrients, and prolonged nutritional deficits can lead to significant menstrual irregularities. Studies in animals and humans show that reduction of energy availability to less than 30 kilocalories/kilogram of fatfree mass (FFM) per day causes dramatic changes in the normal patterns of hormone secretion. Energy availability is calculated using caloric intake, exercise energy expenditure, and FFM. Low energy availability alters the levels of numerous hormones that can affect the menstrual cycle, including luteinizing hormone (LH), insulin, cortisol, growth hormone, insulin-like growth factor 1 (IGF-1), thyroid hormone, leptin, and ghrelin.

Menstrual irregularities in female athletes are caused by disruptions in the normal hormonal signaling between the hypothalamus, pituitary gland, and ovaries. A variety of menstrual abnormalities may occur, including luteal suppression (shortened luteal phase of the menstrual cycle), anovulation (impairment of follicular development), oligomenorrhea (>35 days between cycles), primary amenorrhea (delayed menarche or the absence of menses by age 15 in girls with secondary sex characteristics such as breast development and pubic hair), and secondary amenorrhea (absence of at least three consecutive menstrual cycles after menarche has occurred).

Osteoporosis

Severe nutritional deficits due to disordered eating (including inadequate calcium and vitamin D), low sex hormone levels (including estrogen, progesterone, and testosterone) due to amenorrhea, and high cortisol levels due to stress can all lead to low bone mineral density (BMD). In women, 90% of adult bone mass is acquired by age 16, and peak bone mass is achieved by around age 30. Thus, disruptions in the menstrual cycle during adolescence and early adulthood have a profound effect on bone health and may result in a lost opportunity to attain peak bone mass. Women with low BMD can fracture more easily with minimal trauma. Initially, this may present in a female athlete as repetitive stress fractures. Later in life, debilitating spine and hip fractures may occur.

Diagnosis

In general, screening for the triad should be done in preparticipation exams, in annual health visits, and whenever an athlete seems to exhibit some of the characteristics or consequences of the triad (weight loss, abnormal eating behaviors, stress fractures, etc.).

Information about dietary habits, weight fluctuations, workout routines, menstrual patterns, body image, stresses, and history of fractures should all be obtained. As mentioned previously, athletes may exhibit all or parts of the triad, so when one abnormality is noted, screening for the other two components should be performed.

Some health professionals rely on BMD scans, such as dual-energy X-ray absorptiometry (DXA), to diagnose low BMD. However, these should be interpreted with caution in both adolescents and athletes. Adolescents may not have attained their total peak bone mass, so the results need to be compared with those of adolescents of comparable developmental age—which is based on both chronological age and age at menarche. In general, athletes have higher BMDs than the sedentary controls used as the reference populations for BMD guidelines. Much of the activity athletes engage in involves weight bearing, which can increase bone remodeling and BMD. Thus, if an athlete has a BMD result on the low end of normal compared with the reference population, this may indicate a lower than expected value and is a matter of concern.

In addition, menstrual irregularity in a female athlete should not automatically be assumed to be the result of her exercise and/or dietary habits. An athlete with amenorrhea should always be referred to a physician who is comfortable investigating the cause of the menstrual disorder. Absence of menses may be caused by energy and nutritional deficits in an athlete, but other causes such as pregnancy, pituitary tumors, polycystic ovarian syndrome, and other endocrine abnormalities should be considered.

Treatment

Unfortunately, there are no universal guidelines for management of women with the female athlete triad. Treatment of amenorrheic women with estrogen and progesterone replacement has not been effective in improving BMD. Instead, correction of the energy deficit has proven much more successful in restoring BMD. Estrogen is only part of the bone-building equation, as other hormones affected by caloric restriction (insulin, cortisol, growth hormone, IGF-1, thyroid hormone, leptin, and ghrelin) all play critical roles in skeletal health. Improving the energy deficit to allow weight gain and resumption of the normal menstrual cycle has shown the greatest benefit.

Achievement of optimal health for the female athlete with the triad requires a team approach. Some athletes improve with help from a nutritionist and a physician. The nutritionist may help target nutritional deficits, estimate caloric needs, and give suggestions for increasing the intake of various vitamins and macronutrients. Physicians can help manage bone healing, rule out other causes of menstrual irregularity, and possibly add medications to treat comorbidities such as depression. Other athletes need the services of these two professionals, along with a psychologist/psychiatrist, an exercise specialist, and other resources.

Addressing the causes of disordered eating, focusing on maximizing training benefits for performance and health, and finding other ways to assist the athlete in her recovery are keys to improving the female athlete's condition. With a multidisciplinary approach involving coaches, trainers, friends, family members, and health professionals, female athletes at risk for the triad, as well as those already affected by it, can receive the help they need to remain physically active and healthy for the rest of their lives.

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See also Eating Disorders; Menstrual Irregularities; Nutrition and Hydration

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Femoral Anteversion (Turned-In Hips)

The femur is the long bone in the leg that extends from the hip to the knee; the word *anteversion* means leaning forward. *Femoral anteversion* is defined as the leaning forward of the femoral neck with respect to the rest of the femur. This causes the leg on the affected side to rotate internally or twist inward toward the midline of the body.

Normal Anatomy

All children are born with some degree of femoral anteversion, which decreases naturally as the child grows. The angle between the plane of the femoral neck and the plane of the knee is approximately 40° at birth and declines to 15° by age 10. Because the femur normally has some degree of anteversion as children grow, it is only considered abnormal if it is significantly different from the average value for children of the same age.

Prevalence

Femoral anteversion occurs in up to 10% of children. It is more common in females than in males and is usually noticed between the ages of 3 and 6 years.

Diagnosis

Parents usually notice that their child is walking with his or her toes pointed inward. A child with femoral anteversion might appear more clumsy than his or her peers and tend to trip or fall more often. Parents usually worry most about the appearance of the child's leg or legs while walking or running. In addition, children with femoral anteversion usually prefer to sit in a "W" position because it is more comfortable for them. A child with femoral anteversion is rarely in pain.

The physician will observe the child walking and running and standing straight. In a patient with femoral anterversion, in-toeing will be evident, and the patient will have kneecaps that also turn in toward the middle of the body. Femoral anteversion is an inherited trait, and thus the doctor may ask if anyone else in the family had a similar problem. X-rays are usually not helpful in making the diagnosis.

Etiology

The exact mechanism that causes femoral anteversion is not known. It is considered to be an abnormality of development. As a baby grows inside mom's uterus, the femur may grow with abnormal rotation based on its position in utero and genetic factors.

Treatment

A normal baby is born with approximately 40° of femoral anteversion. This angle naturally decreases as children grow; thus, no treatment is necessary if the anteversion is within the normal range. If the anteversion is greater than the normal values, doctors will generally take the "watch and wait" approach and monitor the children closely as they grow. Studies have shown that night splints and special shoes do not help this condition.

Is Surgery Ever Needed for Correction?

Surgery is only indicated if the child is at least 8 years of age and if the angle of anteversion is greater than 50°. Anteversion naturally resolves as the child grows in 99% of the cases.

The only surgical treatment currently used for older children who still have severe anterversion is called *femoral derotational osteotomy*. A pediatric orthopedic surgeon will intentionally cut the femur, rotate it away from the midline, and then fix or secure it in a more correct anatomical position.

Prognosis

Since the anteversion usually naturally resolves by early adolescence, the prognosis is generally good. Children who have natural resolution of the anteversion are not thought to be at increased risk for hip or knee arthritis or athletic difficulty later in life.

Femoral Anteversion and Athletic Performance

Children with femoral anteversion have more inward rotation of their legs than children who do not have anteversion. As a result, children with femoral anteversion may have inward-pointing feet and a more difficult time running, depending on the degree of anteversion present. They may tend to be more "clumsy" than their peers and can be more prone to tripping over their own feet. As the child grows and the anteversion naturally resolves, these issues also tend to resolve. Children with more prominent anteversion that requires medical intervention are likely to have even more difficulty with running and sports until the anteversion is corrected.

Furthermore, while the child has anteversion, the biomechanical forces transmitted throughout the leg are suboptimal and may cause more strain on the knee than usual by changing the Q angle.

Katherine Stabenow Dahab

See also Biomechanics in Sports Medicine; Bowlegs (Genu Varum); Flat Feet (Pes Planus); High Arches (Pes Cavus); Hyperextension of the Knee (Genu Recurvatum); Knock-Knees (Genu Valgum); Miserable Malalignment Syndrome; Q Angle

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Femoral Neck Stress Fracture

Stress fracture or fatigue fracture of the femoral neck is an uncommon problem. Typically, these injuries arise from repetitive overuse and are most often seen in athletes and military recruits. Unlike stress fractures in other parts of the skeleton, however, the potential for serious long-term consequences from femoral neck stress fractures is high. Anyone involved in the treatment of these groups of patients must always consider femoral neck stress fracture as a potential diagnosis, as early diagnosis and treatment are essential.

Anatomy

The femoral neck represents a bridge between the ball of the femoral head and the shaft of the femur. Significant forces are transmitted through the femoral neck during normal gait. Even higher stress can be seen with athletic activity. Constant stress through the femoral neck produces a phenomenon whereby bone density is higher at the medial part of the femoral neck, known as the *calcar*. The stress in this area is mostly compressive in nature. The opposite side of the femoral neck is less dense, and the forces are mostly in tension. Continual stress through these regions of the femoral neck allows the bone to maintain its integrity by adjusting itself to compensate for activity level.

The blood supply to the femoral head proceeds in a retrograde or backward fashion. Any fracture of the femoral neck can compromise this blood supply. The greater the displacement of the femoral neck fracture, the higher the chance of injury to this extremely important vasculature. If the femoral head loses its blood supply, the bone may die in a process known as avascular necrosis. This has significant long-term, deleterious consequences.

Causes

Bone is living tissue that is constantly changing. Bone density is increased in areas of the skeleton where stress is great and decreased in areas of less stress. Fracture of bone occurs when the force applied exceeds its mechanical strength. Unlike dramatic fractures caused by violent trauma, where the injury force quickly overwhelms the bone's strength, stress fractures arise from repetitive overuse. The skeleton can compensate for increased, repetitive activity by increasing the amount of bone in the area to reinforce itself. However, when inadequate time is allowed for rest and bone remodeling, a stress fracture occurs. Typically, stress fractures occur when athletes suddenly increase the intensity and/or duration of their workouts. Many other factors contribute to stress fracture, including overall patient health, medications, nutrition, activity type and level, and bone strength. Additionally, athletes with significant muscle fatigue are more susceptible to femoral neck stress fractures. Fatigue of the strong stabilizing muscles around the hip joint transmits more force to the femoral neck.

Epidemiology

In general, femoral neck stress fractures occur in two groups stratified by age: young and old. Because this injury is caused by constant and repetitive overuse, the younger groups that suffer it are commonly endurance athletes and military recruits. The second group that develops this condition is made up of older, less active people whose bone quality is poor. However, this condition can occur in any age-group and at any activity level.

Symptoms

The most common symptom of a femoral neck stress fracture is pain. This pain usually starts slowly and worsens over a period of time. Pain is usually located in the groin but can also present anywhere around the hip joint. Activity will typically make the pain worse, and rest will relieve it. Range of motion and loading of the hip joint will reproduce the pain. Other local symptoms such as swelling and tenderness will normally be absent given that the femoral neck is relatively deep and surrounded by large muscles. The patient will usually present a history of a sudden increase in activity intensity or duration or a new type of activity.

Diagnosis

Rapid and accurate diagnosis of femoral neck stress fractures is important to minimize the risk of complications. A high index of suspicion must be maintained in the athletic population presenting with groin pain of unknown cause. Various imaging studies can be used to confirm the diagnosis that is suggested from the history and the physical exam. Radiographs are usually the first step; however, they can often be normal, especially in the early stages of stress fracture formation. Usually, some form of advanced skeletal imaging is necessary to confirm the diagnosis. Bone scan is very helpful in confirming the diagnosis. It will show increased uptake at the area of stress fracture. Magnetic resonance imaging (MRI) is also able to show the fracture and gives a clearer picture of the fracture pattern.

Classification

Classification of femoral neck stress fractures helps in selecting the correct method of treatment. The most commonly used system divides fractures into three types: compression side, tension side, and displaced. Compression-side fractures are those that arise on the medial side of the femoral neck. The forces in this area are compressive in nature. Tension-side fractures arise laterally on the femoral neck, where the forces are mostly tensive in nature. Displaced fractures are those that occur completely across the femoral neck and in which the alignment of the femoral neck is disrupted.

Treatment

The overall goal in the treatment of femoral neck stress fractures is twofold. The first is to provide the optimal environment for the fracture to heal. The second is to minimize the chance that the fracture will displace. The consequences of displacement are dire and are discussed below. These goals are achieved by a combination of modalities. The addition of cross-training exercises will help prevent future recurrences.

Nonoperative Treatment

The first step in creating a good fracture-healing environment is to correct as much as possible those factors predisposing the stress fracture. This includes metabolic, medical, nutritional, and mechanical factors. Often, this requires a multidisciplinary team approach with the input of several different specialists.

Compression-side stress fractures that involve a small portion of the entire femoral neck have a low risk of displacement. This type of fracture is treated nonoperatively. Restricting and modifying the patient's activity is essential. The bone must be given enough rest and relief from the inciting activity so that it can heal itself. The patient is not only restricted from athletic activity but also restricted from putting any weight on the affected limb at all. Non–weight bearing is achieved with the use of crutches. The duration of this treatment should be a period of 4 to 6 weeks, during which the injured bone has a chance to remodel. Radiographs are used to follow the healing of the fracture. Unrestricted return to sports is usually held off for an additional 4 to 6 weeks.

Operative Treatment

Tension-side fractures have a high rate of displacement and are therefore treated more aggressively. Surgical stabilization of these fractures, with the use of several large screws placed across the femoral neck, is usually recommended. Once the screws are in place, the chances of the fracture displacing are rare. After surgery, full weight bearing is allowed; however, unrestricted return to sports is delayed until the fracture is healed and asymptomatic. Radiographs are again used to follow the fracture healing.

Displaced femoral neck stress fractures require urgent surgical management. Once the fracture displaces, the blood supply to the femoral head is compromised. The fracture must be realigned and stabilized with several large screws to decrease the risk of avascular necrosis of the femoral head. This complication can occur nonetheless despite urgent and appropriate surgical treatment; the disruption of the blood supply to the femoral head occurs at the time of fracture displacement. Postoperative management of displaced femoral neck fractures is similar to management of the tension-side fractures but often is individualized.

Complications

Most stress fractures of the femoral neck go on to heal with proper treatment. Others, however, can result in complications. The most serious and dreaded complication of a femoral neck stress fracture is avascular necrosis (AVN) of the femoral head. Interruption of the blood supply to the femoral head from a variety of causes (not always from fracture) causes the bone and cartilage to die. This leads to degeneration of the hip joint in varying degrees depending on how much of the femoral head is involved. Destruction of the joint surfaces, termed *arthritis,* ensues. Such events in young athletes have dire and long-term consequences.

Other, less common complications include failure of the bone to heal or for the fracture to heal in a poor position. Any of the above conditions can predispose the hip joint to early degeneration and arthritis. No good options exist for the successful treatment of advanced joint degeneration or arthritis in the younger population.

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See also Avascular Necrosis of the Femoral Head; Fractures; Hip, Pelvis, and Groin Injuries; Stress Fractures

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Femoroacetabular Impingement

Femoroacetabular impingement (FAI) is a musculoskeletal disorder of the hip, referring to the repetitive contact of the femoral neck and the lateral rim of the acetabulum, and the subsequent trauma and injury that result. The symptoms may be mild, but FAI can progress, lead to other mechanical dysfunctions, and potentially create osteoarthritis significant enough to require hip replacement surgery.

Mechanism

Hip impingement occurs because of two primary mechanisms: (1) cam impingement and (2) pincer impingement. This can be visualized easier as a problem with the ball-and-socket joint.

- *Cam impingement* is caused by problems with the ball, or shape, of the femoral head that is trying to fit into the acetabulum. In many cases, the femoral neck is too thick or has extra bony thickening or spurring at the head-neck junction. Some femoral heads are ovoid and cause more impingement than the normal, spherical head.
- *Pincer impingement* is caused by problems with the socket, or *acetabulum*. The rim of the acetabulum comes into contact with the femoral head-neck junction. With repetitive use, pincer impingement stresses the bone and injures the soft tissue structures, specifically the acetabular labrum. This often occurs because of a socket

that is too prominent or deep (coxa profunda) or turned backward (retroversion) so that the front wall covers the femoral head more than the back.

Whichever mechanism causes the problem, identifying the causative factors for each is important. Legg-Calvé-Perthes disease is a juvenile disorder that affects the physis of the femoral head, but it can cause subtle bone thickening that can lead to impingement years later. Heredity plays some role in passing along hip anatomy that is set up for impingement, but no research has definitively found a marker or gene associated with impingement.

Many athletes can get an FAI, but those who are just nominally active can have symptoms as well. Activities that are correlated with increased incidence of FAI include ice hockey, horseback riding, yoga, football (American), soccer, ballet, dance, acrobatics, golf, tennis, baseball, lacrosse, field hockey, rugby, bike riding, cycling, martial arts, deep squatting activities such as power lifting, rowing sports (kayaking, sculling/rowing), and even car riding (in a deep-seated position).

Other Conditions

Because the hip and pelvis region is so complicated and the symptoms are not always straightforward, many conditions can be confused with FAI.

In some cases, patients may be told that they have hip dysplasia, either instead of or along with FAI. This can be confusing, and the conditions need to be differentiated. A hip with dysplasia typically suffers from a socket that is too shallow, that does not cover enough of the femoral head to support weight bearing. This increases the load on the lateral acetabulum and soft tissue structures, causing labral tears, instability, and premature osteoarthritis.

A hip can have dysplasia as well as FAI, and both can contribute to the patient's pain. However, surgical correction for each condition is different, so an accurate diagnosis is even more important when surgery is considered.

History

A patient will typically complain about pain in the front or lateral side of the hip, toward the level of the greater trochanter. Many patients will use their index finger and thumb to form the letter "C" and place their hand against their side and describe their pain as following their fingers. This symptom is relatively sensitive for the presence of hip pathology.

Pain can radiate down the sacroiliac joint and buttocks. Patients will complain of specific activities causing their pain, even things such as sitting and driving in a car for a while. Sitting cross-legged or on a short chair or stool can cause trouble when standing up again.

Catching or snapping in the hip region, stiffness, and loss of motion are also common complaints.

Often, symptoms are improved but not resolved with conservative therapy, and many patients will recall pain in the hip region for many years before seeking care.

Physical Exam

Clinical exam involves basic palpation, range of motion, and strength testing, which is cursory for

Conditions With Symptoms That Can Mimic FAI

- Hip dysplasia (adult form)
- Lumbar spine pain
- Lumbar radiculopathy (sciatica)
- Sacroiliitis
- Greater trochanteric bursitis
- Piriformis syndrome
- Iliopsoas tendinitis/tendonitis/tendinosis (hip flex or inflammation)
- Groin pull
- Sports hernia
- Iliac apophysitis (inflammation of a frontal hip growth plate)
- Quadriceps hernia/strain
- Chronic pain syndromes
- Psychosomatic pain disorder

Source: Adapted in part from Ganz R, Parvizi J, Beck M, Leunig M, Notzli H, Siebenrock KA. Femoroacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res.* 2003;(417):112–120.

orthopedic examinations. The hip exam involves two specific maneuvers, (1) the Scour test and (2) the Patrick or fabere test, both done with patients lying on their back:

Scour test: The thigh is flexed, internally rotated, and adducted. The clinician moves the thigh around the edge of the socket in somewhat of a semicircle. A normal hip would not hurt with this maneuver, so pain or catching in the front hip is considered positive.

fabere test: The leg is moved into a figure-four position, with the ankle resting on the opposite thigh, just above or at the knee. The clinician gently pushes down on the knee that is bent while holding the opposite side of the pelvis down. Pain in the front of the hip indicates hip pathology, while pain elicited in the lower back suggests sacroiliitis.

Trigger points are commonly found on the tensor fascia lata and gluteus medius muscles, the proximal hamstring tendon, the sacrotuberous and sacroiliac ligaments, and the anterior hip and hip flexor tendon region.

Hip impingement causes inflammation of the hip capsule, or synovitis, and that reaction can lead to weakened gluteal and hip rotator muscles (e.g., the piriformis and obturator muscles). This can lead to chronic pelvic malalignment, core instability, leg length discrepancies, and chronic lumbosacral dysfunctions. This is important to remember in patients with long-standing complaints of pain or problems in one area that do not improve with time or treatment. The source of those problems may be the hip joint.

Diagnostics

History and physical exam are usually enough to diagnose FAI, and imaging procedures help clinicians by confirming diagnoses and establishing prognosis and treatment options.

X-rays should include a frontal standing PA (posterior anterior) view of the pelvis and "frog-leg" views of the hip joints. Early degenerative changes, depth and position of the acetabulum, and bony irregularities of the femoral head and neck should be evaluated.

Computed tomography (CT) *scan* is a computerized radiographic exam that shows the bony anatomy better than any other imaging modality, especially thin-slice CT scans with three-dimensional image rendering. It benefits the surgeon who is contemplating surgery, but it is not essential or necessary for diagnosing FAI.

Magnetic resonance imaging (MRI) uses a powerful magnetic field to differentiate soft tissue on images, something that CT scans cannot do well. Therefore, it is used consistently to aid in the diagnosis and prognostic staging of FAI. Most physicians order an MR arthrogram, where a specialist injects a contrast agent into the hip joint to enhance the view of the labrum and articular cartilage. A normal MRI scan taken under normal circumstances is insufficient to diagnose subtle changes and small areas of damage. However, a few programs in the United States, most notably at the Hospital for Special Surgery in New York, run an MRI protocol without contrast that is clear and effective enough for physicians to make a diagnosis.

Treatment

Since FAI is a relatively new condition, little research exists to support specific treatments in treating it. Conservative therapy is always the first approach, but many patients will need to modify their activities to accommodate this treatment. A rigorous core-strengthening program should be started, but it should not involve high ranges of hip motion, particularly in flexion and abduction. Improving flexibility and correcting dysfunctions and alignment problems can help relieve the symptoms.

Surgical intervention should be considered right away if the hip shows degenerative arthritis, labral tears, or anatomical factors that lead to FAI or dysplasia. The goal is to preserve the hip joint and prevent permanent degenerative changes of the articular cartilage; once degenerative changes occur, the only effective corrective options are hip resurfacing or replacement.

If the articular cartilage is intact and the condition is identified early, then procedures can be done that preserve the hip. These include the following:

Hip arthroscopy: to repair a torn labrum, remove loose bodies

Surgical hip dislocation/osteoplasty: to reshape the acetabular rim, shave down thickening or spurring of the femoral head-neck junction

Microfracture technique: to stimulate new cartilage growth in an arthritic area of the acetabulum (usually done during arthroscopy)

Periacetabular osteotomy: to reorient a dysplastic acetabulum in order to absorb load over a broader area.

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See also Core Strength; Hip, Pelvis, and Groin Injuries; Hip, Pelvis, and Groin Injuries, Surgery for

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Fever

Fever is an elevation of core body temperature; in medical terms, fever is a temperature over 38 °C (100.4 °F). Fever is involved in the body's immune response and most often occurs as a result of an infection. Participation in sports while the athlete is febrile is a controversial topic in sports medicine.

Regulation of Body Temperature

Normal body temperature is 37 °C (98.6 °F) when taken orally. However, variability exists between people, and temperature may fluctuate depending on the time of day, weather, exercise, menstrual cycle in women, and age; therefore, an individual's baseline temperature may deviate slightly from 37 °C. For about 99% of the population, normal oral temperature ranges from 36.0 to 37.7 °C (96.8–99.86 °F).

An individual's body temperature is set by the hypothalamus, an area in the base of the brain that acts like a thermostat, maintaining normal temperature through heating and cooling mechanisms. The main heating mechanism is the constriction of blood vessels in the periphery of the body, which decreases heat loss from the skin; another is shivering, which causes a release of heat from the muscles. Sweating acts as the body's chief cooling mechanism by causing the loss of heat through evaporation.

Pyrogens

Fever is the result of the hypothalamus raising the body's temperature set point in response to a stimulus (termed a *pyrogen*). In the cascade that leads to fever, pyrogens cause specific white blood cells called phagocytes to produce a number of proteins, including interleukins, interferons, and tumor necrosis factor alpha. These proteins then induce the production of prostaglandins, which subsequently leads to a resetting of the body's temperature set point.

In response to the elevation of the set point, the hypothalamus activates the heating mechanisms illustrated above, and the body's core temperature rises until the new set point is reached.

Most commonly, the inciting pyrogen comes from outside the body and, thus, is termed *exogenous*. Infectious agents (viruses or bacteria), medications, and drugs can all act as exogenous pyrogens. Occasionally, fever may be caused by a stimulus from within the body (an endogenous pyrogen); examples of conditions that produce these pyrogens are autoimmune and other inflammatory diseases, brain injury, and some forms of cancer.

Overall, infectious agents are by far the most common cause of fever. Examples of common viral and bacterial illnesses that cause fever are colds, the flu, and gastroenteritis. Additionally, some serious infections are known to cause fever, including meningitis, endocarditis, and sepsis; however, these conditions are relatively rare and usually have associated symptoms that indicate a significant underlying illness.

Typically, the pyrogen can be determined by a thorough history, physical exam, and laboratory testing as necessary.

Fever and the Immune System

Fever acts as a part of the body's defense system against infection. Most bacteria and viruses have evolved to function best with a surrounding temperature of around 37 °C (98.6 °F); therefore, the increase in ambient temperature that occurs with fever directly decreases the ability of those organisms to survive. Furthermore, fever activates the body's immune system, causing increased production of white blood cells, which in turn fight the infection that initiated the fever; in the presence of fever, these white blood cells also become more mobile, multiply faster, and are better able to destroy the invading microorganisms.

Treatment

In the vast majority of cases, treatment of the fever itself is not necessary, especially as it aids in the immune response. However, a temperature above 41 °C (105.8 °F) may lead to neurological damage and possible death if persistent. In these instances, the fever should be treated with antipyretic medications, such as acetaminophen or ibuprofen, until the underlying cause can be elicited and treated.

At this time, no clear principle exists for the treatment of fever in cases where temperature is below this level, as scientific studies in this area are conflicting. The decision is therefore left to the patient and the treating physician.

Fever in Sports Medicine

Fever has a number of effects on the body's physiology that may influence athletic performance. It increases cardiopulmonary effort and decreases peak exercise capacity and endurance. It may also decrease muscle strength, coordination, and concentration, so athletes who participate in their sport while febrile may be at a greater risk of injury, although no studies have been done to document this. Additionally, fever puts an athlete at greater risk for heat illness.

Due to the effects of fever on physiology and its hypothetical effects on performance and safety, the American Academy of Pediatrics recommends that febrile pediatric athletes should not participate in sports. The policy with adult athletes is somewhat more controversial, and no clear consensus exists. A similar strategy is suggested by the journals *Evidence Based Sports Medicine* and *The Physician and Sportsmedicine:* Allow athletes with cold symptoms (confined to their head and neck area) to participate in a limited fashion, while disqualifying athletes with symptoms below the neck, as these may indicate a more serious infection. However, the suitability of this approach has not been clinically studied. Therefore, as no specific and tested policy exists, sports participation with fever is often based on the specific characteristics of each case and the preferences of the health care provider making the decision.

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See also Blood-Borne Infections; Infectious Diseases in Sports Medicine; Pulmonary and Cardiac Infections in Athletes

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Field Hockey, Injuries in

Field hockey is a team sport comprising 11 players, 10 field players and one goalkeeper. Worldwide, it is second only to soccer in popularity among team sports. Players use a one-sided, curve-toed stick that is approximately 36 inches (in.; 36 in. = 91.4 centimeters) long to move a hard plastic ball down the field in an attempt to score within the goal area. The left hand is at the top of the stick, and the right hand is below this in variable positions depending on whether the player is dribbling, hitting, or playing defense. Most injuries arise as a result of being struck by a hard-hit ball or accidentally by the hockey stick, primarily on the hand, lower legs, and head or face. Other injuries are overtraining injuries, acute muscle strains (hamstring and quadriceps), or ligamentous injuries such as ankle sprains or ACL (anterior cruciate ligament) tears, which one might find in any sport that involves changing direction quickly and playing in close proximity to other players. Although field hockey is a noncontact sport, incidental contact occurs frequently.

Types of Injury

The box below lists some of the injuries that field hockey players may be prone to.

Contusions/lacerations/ fractures	Fingers and hand
	Face and head
	Lower leg and feet
Ligamentous	Ankle sprain
	ACL (anterior cruciate ligament) tear
Muscle strains	Hamstring
	Quadriceps
	Groin
Overuse	Shin splints
	Stress fractures
	Patellofemoral syndrome
	Low back pain
Head injury	Facial fractures
	Lacerations
	Concussion
Eye injury	Infrequent but can be serious

Protective Equipment

Players wear mouthguards and plastic or foam shin guards that protect the lower leg and ankle. Many states require high school students to wear a goggle-type eye protection, but this is optional at the college and international levels. The use of close-fitting gloves, with padding over the top of the fingers, can help reduce both finger and hand injuries. The goalkeeper is protected from head to toe with a helmet, a throat protector, a chest protector, padded pants, arm and hand pads, sturdy leg guards, and "kickers," which go over the feet to provide protection as well as a way to clear the ball away from the goal area. Despite facial injuries being fairly common in field hockey, helmets are not currently part of the equipment for field players. Controversy remains over the introduction of such equipment that might lead to more aggressive play and thus make the game more dangerous rather than less. Face masks are temporarily worn by field players on the penalty corner, a situation where the ball is hit sharply toward the goal from 16 yards (yd; 1 yard = 36 in.) away. Deflections by the goalkeeper or other players may dangerously redirect the ball toward the defender's head.

Field Hockey Surfaces

Field hockey is played on a variety of surfaces, most commonly grass at lower levels and some sort of artificial surface at the collegiate and international levels. Hand injuries tend to be more frequent on artificial surfaces, likely due to the higher speeds and different stopping techniques that move the hand closer to the ground and closer to danger. Artificial surfaces include products such as AstroTurf, which is basically a short, fiber carpet that is rolled over a concrete surface. "Field turf" is a longer, blade carpet that is interspersed with rubber pellets or sand. Field turf is a softer surface for landing and is felt to be less of a risk for concussion, turf toe, and joint injuries than the synthetic carpet over concrete. However, field turf tends to be slower and less "true" for a rolling ball than AstroTurf, the preferred surface at higher levels of play. Artificial surfaces should be watered prior to use to prevent athletic shoes from catching and locking and thus leading to injuries such as ACL tears. Water also helps keep the ball on the field surface to prevent bouncing and helps reduce abrasions when sliding or falling on the surface. Abrasions can be quite severe when falling on a dry turf. Because the artificial surfaces are significantly hotter than grass fields in the summer months, applying water can also temporarily cool the surface. Watering is generally done before the game and at half-time.

Preventing Injury

Rule enforcement is important for preventing dangerous play that might lead to unnecessary injury. Using the stick or undercutting the ball in a dangerous manner or hitting the ball intentionally or recklessly into other players is a serious foul. Supervision by competent coaches and teaching of proper hitting and tackling techniques can help reduce injuries. Safe field conditions are critical. Uneven surfaces from holes or ruts need to be corrected and loose objects, such as rocks, removed. Artificial surfaces have generally eliminated this problem. Proper footwear for the surface being played on is important in preventing catching or slipping of the foot.

Management of Injuries

Use of braces or taping may help get an athlete back to sport or help prevent injury in susceptible players. Athletes with stable finger fractures may be allowed to return to play with buddy taping. Tight-fitting face masks may be used by players who have suffered nasal fractures or other stable facial fractures. Padding of the injured area may help prevent recurrent injury to the same area.

Leslie W. Milne

Further Readings

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Fieldside Assessment and Triage

Fieldside assessment and triage of an injured athlete are essential skills for any sports medicine specialist. The initial assessment is crucial to direct the provider toward the best course of action. The decision-making process can often be challenging. If a serious injury is found, one must be prepared to manage the athlete until transfer to a medical facility can be arranged. If the injury is a minor one, the practitioner can assess and test the athlete before sending him or her back to the field. In between these extremes, the physician must make a decision as to whether to observe the athlete for a short while or to refer the injury for further investigation or management. The process of triage and assessment described in this entry allows physicians to quickly recognize those with severe injuries and transfer them to an appropriate medical facility quickly.

Early planning and rehearsal are the best methods of preparation, preventing delay in transfer and medical care in the event of an emergency. Perhaps the most important point to remember is that anything can happen and seemingly innocuous problems can rapidly become life threatening if not considered in a structured manner. This entry is intended to be a rough guide for general readers, students, and professionals with an interest in sports medicine. It will describe what happens when an experienced physician examines an injured athlete on the field. The "ABCDE" approach to assessment is discussed to introduce a standard plan for the primary and secondary survey. The ABCDE survey is designed to detect life-threatening injuries, such as those caused by airway, cervical spine (C spine), breathing, circulation, circulatory, and environmental stressors. The most common cause of nontraumatic sudden death in an athlete is cardiovascular, with dehydration, drug use, and elevated or decreased core temperatures being medical risk factors to consider. This entry provides the basic principles to decide whether an athlete can return to the field of play or not. Many of the elements of the secondary survey are discussed elsewhere in this volume, but issues relevant to triage and assessment are also discussed here.

Preparation and Planning

The most important feature of providing good medical triage and assessment at any sporting event is good preparation. The medical team should fully understand both the sporting demands of the event as well as the dangers that can arise from competing. The team should have a good idea of their roles, and a consistent plan should be followed in the event of serious injury. Outside health facilities will have their own emergency medical protocols, which should be reviewed prior to making any preparations. Planning starts with organizing a staff that can deal with a number of competitors, with the risk level being understood and taken account of. The medical team should not only consider the common emergencies that can occur but also be aware that natural disasters or sudden weather changes can put athletes at risk. Ambulance routes should be planned in advance, and pre-event practice should be standard among the team. Only by rehearsing will the team gain familiarity with communication systems as well as emergency protocols. This should be done through regular workshops and training exercises. Ideally, members of the medical staff should be certified in first aid and cardiopulmonary resuscitation.

A well-stocked medical bag, good communications, and accurate weather assessment will go a long way in dealing with any athlete's injuries. Preparation of equipment is vital and should be tailored to the event being covered. A sample list of common equipment is outlined in Table 1.

Communication is a vital part of assessment and triage as the physician must be able to activate emergency protocols and contact emergency services for rapid transfer of acutely ill athletes. In mass participation events, a main means of communication is recommended with a secondary

Table 1 Suggested Equipment List for a Medical Bag

Airway and Ventilatory Supplies	*Circulatory Supplies*	*Transport*	*Medications*	*Miscellaneous*
Rigid cervical spine collar	Intravenous catheters	Spine board + head blocks and tape	Adrenalin (epinephrine), 1 in 10,000 solution	Sterile gloves
Bag valve mask	Intravenous fluids	Stretcher	Oral/sublingual nitrates	Alcohol swabs
Oropharyngeal airway	Intravenous line tubing	Crutches	Aspirin	Athletic tape
Nasopharyngeal airway	Tourniquet		Beta-agonist inhaler	Splints
Intubation equipment	Automatic external defibrillator		Aerochamber	Ice
Laryngoscope			Analgesia	Gauze and bandages
Crycothyroidotomy kit			Oral anti-inflammatory drugs	Suture kit
14-gauge cannula for tension pneumothorax			Antibiotics	Stethoscope
Oxygen tank and reservoir			Oral glucose tablets	

method of contact as backup. Radios or cellular phones are often used as means of communication. Simple procedures such as having sufficient spare batteries and good radio protocol can eliminate failures of this network. At a minimum, the physician should also carry a fully charged cell phone for emergency use. The numbers of local emergency services and any other important local resources should be kept close at hand and distributed among the team.

Anticipation of weather hazards is important for all outdoor events. Heat illness is a common concern in sports events in hot, humid environments, particularly if the athletes are exposed to direct sun for prolonged periods of time. Ambient temperature above 28 °C (82 °F) can lead to heat-related injury, so particular attention should be paid to keeping athletes well hydrated. In cases of extreme heat, it is better to practice indoors, increase water breaks, and shorten high-intensity workouts as necessary. Games may need to be rescheduled to cooler times, such as the morning or evening, or, more rarely, cancelled in the event of high temperatures. Conversely, one should consider hypothermia in cool weather with any fall in temperature or increased windchill. Athletes are at risk in water sports when the water temperature is below 10 °C. If the athletes are ill prepared, this can become a problem even in relatively mild conditions. Rain, snow, and sleet can be dangerous in events of long duration as they can further reduce the temperature of athletes and make transfer or rescue much more challenging. Athletes and coaches should be made aware of this, allowing them to either be prepared by wearing warm clothing or consider postponing the meet.

Primary Survey

In the case of an athlete who has had a fall, a primary survey should be sequentially performed. This involves assessment of vital signs and ensuring that the life of the patient is not immediately in danger.

A suggested approach, formulated by the American College of Surgeons, is as follows:

A = *A*irway and cervical spine

B = *B*reathing

C = Circulation

D = *D*isability

E = *E*xposure and environment

This algorithm is a method for carrying out the primary survey in a fieldside assessment in a systematic and simple framework. The goal of the primary survey is to identify and manage reversible life-threatening problems. Each letter of the algorithm is approached and cleared before moving on to the next, and the entire algorithm should be completed before moving the athlete from the field of play. In this way, dangerous situations such as airway compromise or cardiorespiratory emergency can be detected and addressed by even those without great clinical experience. The athlete should not be moved off the field until the primary survey is completed. Body substance precautions include avoidance of contact with bodily fluids and wearing gloves at all times to prevent disease transmission during the resuscitation process.

A: *Airway (and Cervical Spine)*

Airway: What to Look Out For

When an athlete has fallen on the field of play, the assessment should begin by looking at his airway. Lack of oxygen to the brain can lead to irreversible damage within 4 minutes, so any airway blockage needs to be immediately reversed. An athlete struggling for air will often be agitated. Abnormal sounds such as gurgling or gasping suggest a partial obstruction.

How to Assess the Airway

1. A good start can be to ask the athlete's name. If the athlete can respond, then the airway is secure and breathing is occurring.
2. Listen for abnormal breathing sounds; gurgling and whistling suggest partial airway obstruction.
3. Purple discoloration around the lips is called *cyanosis*. This is a sign that the patient does not have enough oxygen in the bloodstream. However, this should be treated with caution as the sign can be misleading in the cold or in individuals with dark skin.

4. Observe for use of muscles around the neck and shoulders for breathing. These accessory muscles may need to be used to assist in the inspiratory effort.
5. Keeping the neck immobile, as described below, the mouth should be inspected for foreign bodies such as teeth or a mouthguard and tongue occlusion of the airway.

How to Manage the Airway

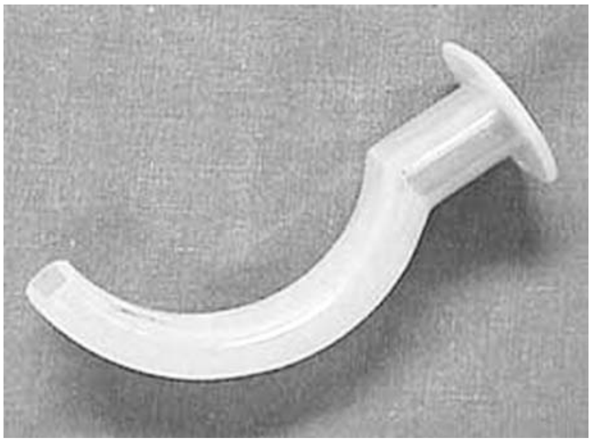
If airway obstruction is suspected, the primary concern is to reestablish a secure and patent airway. The C spine must be protected, especially in an unconscious patient, until serious injury to the neck has been excluded. A maneuver called *in-line manual immobilization* can be used to prevent rotation or sudden movement of the neck, with a medical team member holding the patient's head still with both hands (see image a, this page).

If the tongue is suspected to be causing obstruction, the "chin lift" maneuver can be tried, in which the fingers are placed under the chin and thumbs placed on the lower lip, pulling the chin down and opening the mouth to look in. This technique places the neck at risk of movement and should be performed by those with at least some experience. With the neck immobilized, a "jaw thrust" can also be used, by placing one's fingers behind the angle of the jaw and pulling the whole jaw forward to draw the tongue forward.

If aspiration becomes a problem, then the patient should be turned onto his or her side and suction given. In emergencies, a supportive airway can be inserted, such as an oropharyngeal airway (see image b, this page). This is a rigid plastic tube that can be placed in the mouth, over and behind the tongue, to secure the airway. A nasopharyngeal airway is illustrated in photo (c) below.

If an airway cannot be quickly established, it must be managed by a specialist. In rare cases, a surgical area may need to be created to allow breathing to take place.

(b)

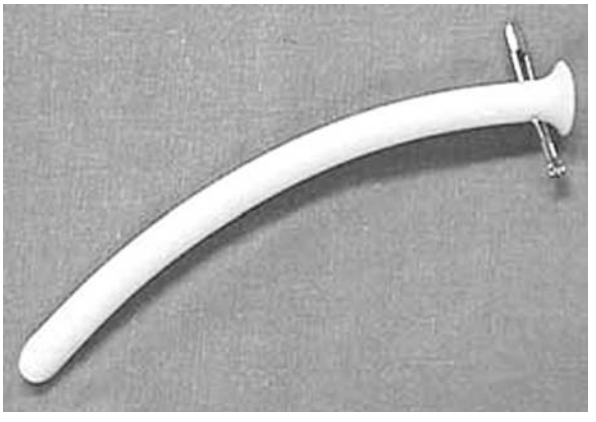


Oropharyngeal airway. It is useful for unconscious patients who lack the gag reflex. A nasopharyngeal tube can be used in awake patients. The long flexible tube is inserted into the nose into the back of the patient's throat, bypassing the tongue.

(a)

In-line manual immobilization of the neck (manual fixation of the neck to prevent further injury)

(c)



Nasopharyngeal airway, used in awake patients with breathing difficulties

Cervical Spine: What to Look Out For

A C-spine injury can have severe consequences, including spinal cord injuries leading to limb paralysis. Unfortunately, it is easy to overlook an injury to the C spine in an emergency situation. Anyone who is found unconscious or is complaining of neck pain following heavy trauma to the head and neck should be considered to have C-spine injury until proven otherwise.

How to Assess the C Spine

Neck immobilization should be carried out routinely at the beginning of any primary survey examination, as part of the assessment of the airway, and throughout the rest of the assessment (see image a, page 512). Serious consequences can follow improper mobilization, however. Helmets and protective equipment should not be removed unless absolutely necessary—for example, to manage medical problems such as protecting the airway. An experienced sports medicine practitioner is needed to gently palpate the spine and safely assess motion in order to rule out C-spine injury.

How to Manage C-Spine Injuries

The C spine should remain immobilized throughout the fieldside assessment to avoid extension, flexion, or rotation of the neck. Manual in-line immobilization of the C spine should be maintained until rigid fixation with a C-spine collar (image d) has been achieved or the neck has been assessed and cleared by an experienced specialist. The athlete may feel that he or she can move but must be prevented from doing so until it is made sure that the athlete has no pain in the neck and that medications or secondary injuries are not distracting the athlete from the pain. Fieldside assistants should avoid using smelling salts to revive players as these can cause a sudden jerking of the head and possible C-spine damage.

The cervical spine is often cleared at the hospital since radiographic imaging of the neck may be required to rule out a fracture.

A maneuver called *logrolling* is sometimes necessary to shift a prone patient into a more practical position on his or her back (see images e, f, and g, p. 514). Logrolling must be performed with a minimum of four people. Three people prepare to move the patient on one side, while the leader takes control of the neck. This lead person must coordinate the logroll and at all times maintain the stability of the neck. Logrolling can be used to move the patient onto a spine board ready for either transportation or further assessment.

(d)

A stiff cervical spine collar maintains in-line immobilization and is often combined with sandbags on either side for transportation.

B: *Breathing*

What to Look Out For

In any sports injury, once the airway is clear and maintained, the breathing must be checked. There are some dangerous conditions to watch out for during sports that cause reduced breathing. A tension pneumothorax is where there is a leak into the lung cavity, enabling air to fill inappropriately around the lung, preventing efficient breathing, and possibly leading to a collapsed lung. Similarly, a hemothorax is due to a penetrating injury to the chest wall, leading to bleeding into the lung cavity. Chest wall trauma, such as rib fractures and/or muscle strains, can also occur, making breathing painful and difficult. Finally, medical conditions can lead to respiratory distress. For example, asthma is a chronic inflammatory disorder of the airways, characterized by airway hyperresponsiveness and reversible airflow limitation. In some athletes, exercise can exacerbate symptoms of shortness of breath, cough, and/or wheezing. *Exercise-induced bronchospasm* (EIB) is a more appropriate term to describe the condition, which is commonly found in asthma

(e)

(g)

(f)

Logrolling. Four people are required for this, one leader and three assistants. The leader's role is to control the head and neck and direct the assistants as to when they should turn the patient. The assistants position themselves at the torso, pelvis, and legs. The leader counts to 3, and the assistants roll the patient up to 90°. The cervical spine can be checked at this stage with the neck collar removed. The roll is completed and the patient placed in a supine position.

Source: All photos displayed in this entry are courtesy of Anthony Gibson.

patients and in individuals with environmental allergies. It can also be found in those with no history of allergies and is thought to be highly prevalent among high school athletes.

How to Assess Breathing

A simple way to first assess breathing is to lean over the athlete and listen for breath sounds while observing for symmetric chest movements. Asymmetry would suggest that the chest wall is damaged and breathing is impaired. A stethoscope can then be used to auscultate over each field. If sounds are not heard, a pneumothorax (air blocking breathing) or hemothorax (blood blocking breathing) should be suspected. Deviation of the trachea from the midline should then be checked. A tension pneumothorax should be suspected if there are decreased breath sounds, tracheal deviation away from the injured side, and evidence of a chest trauma.

How to Manage Breathing Difficulties

If the athlete is found to have a clear airway but is unable to breathe spontaneously, a bag-valve-mask device is used to give supplementary oxygen. The appropriate mask size is selected, and then one or two people work together to produce a seal over the mouth and nose of the athlete. A good method for creating a good seal when only one person is available is to draw the lower jaw (mandible) forward toward the mask with the third and fourth fingers while pressing down with the first and second on the mask. If no ventilation is achieved with this method, it is important to check the airway again for signs of obstruction and to check the equipment for failure. When two caregivers are present, one person can maintain the seal while another squeezes the bag. This should be done at a rate of approximately once every 5 seconds or twice for every 30 chest compressions if they are being performed.

When trying to achieve ventilation, a bag-valve-mask device may not always be available and mouth-to-mouth resuscitation must sometimes be performed. A face shield device is useful to avoid direct contact between the caregiver and the athlete, decreasing the risk of exposure to bodily fluids.

Treatment of tension pneumothorax is urgent and requires skilled management. A large-bore needle must be inserted through the second intercostal space into the chest cavity, to allow relief of the positive pressure built up inside the pleural space. The athlete must be transferred immediately for placement of a chest tube. It should always be remembered that a tension pneumothorax can be fatal.

C: *Circulation*

What to Look Out For

When circulation fails, an athlete may go into "shock." This is a state where the blood flow from the heart cannot match the needs of the body. A patient in shock is in a critical condition, and prompt diagnosis and emergent transfer to a medical facility are imperative. When an athlete is exhibiting signs of shock, the immediate suspicion should be cardiac arrest or arrhythmia. The physical signs to be mindful of are high heart rate (tachycardia), low blood pressure, cold peripheries (indicating vasoconstriction), and a decreased level of consciousness. What makes it more challenging to pick up these signs in an athlete is the naturally reduced resting heart rate and compensation mechanisms that are better than average. This can lead to late diagnosis of imminent shock. Other causes of shock can be dehydration or bleeding into bodily spaces in trauma.

How to Assess Circulation

Feeling the carotid pulse is a good way to start assessing for cardiac arrest or failure. This can be found under the line of the jaw, and if it is absent, a complex cardiac cause or extremely low blood pressure should be suspected. If this is coupled with the signs of shock described above, cardiac arrest or arrhythmia should be assumed and cardiopulmonary resuscitation (CPR) commenced immediately. In young athletes, the most important intervention in a cardiac arrest has been shown to be use of the automated external defibrillator (AED), as it can convert life-threatening cardiac arrhythmias such as ventricular tachycardia and ventricular fibrillation back into a stable rhythm. If a defibrillator is not present, chest compressions should be carried out, with the usual rate being 30 compressions for every two breaths. If a pulse is detected, then heart rate and rhythm should be assessed, and there should be no skipped or extra beats. The resting heart rate should be approximately 60 to 100 beats per minute (bpm) in an adult, but children can have resting pulses up to 140 bpm when younger than 5 years. Trained athletes can have pulses as low as 40 bpm at rest.

How to Manage Circulatory Difficulties

Management of the athlete who shows no pulse first involves starting CPR and immediately activating the emergency system for help. While immediate transfer to specialist care is ideal, if a rhythm can be found to defibrillate, early defibrillation can be lifesaving. In the case of a traumatic wound causing bleeding, pressure with sterile dressings should be applied to the wound to try to stop the bleeding. If possible, the legs should be elevated if signs of shock are present. Intravenous fluids should be administered as soon as possible. Normal (0.9%) saline or Ringer's lactate solution is most commonly used to replace losses. Vital signs should be regularly checked to assess for response to the resuscitation. If no response occurs, the cause of shock has been misdiagnosed and blood loss is not to blame. All cases of shock require immediate transfer to a medical facility for further management.

D: *Disability*

What to Look Out For

Clearing airway, breathing, and circulation constitutes the most important life-saving steps of the primary survey. In the assessment of the disability stage, there are fewer immediate causes of death; however, there are still dangers such as head injuries that can lead to a rapid deterioration in the patient's status. Therefore, the ABCs should continually be reassessed. If bleeding or clear fluid is observed from the ears, nose, or mouth, it may suggest a head injury. Swelling or local tenderness over the skull can suggest an underlying fracture.

Tenderness over the temporal area is particularly worrisome as rapid bleeding in the skull can occur should the underlying artery be torn.

How to Assess Disability

The AVPU is a good method of describing the level of consciousness at the fieldside.

A = *A*lert

V = Responding to *V*oice

P = Responding to *P*ain

U = *U*nresponsive

If the athlete is unable to answer questions coherently, head injury should be suspected. Trauma to the head should be noted by any bruising or bleeding, and immediate medical care should be sought if the athlete is drowsy with a clear head injury. Neurological deficits can be screened for with a brief neurological exam and if the patient is unconscious. Assessments of spontaneous eye movements, speech, and motor function are parts of the Glasgow Coma Scale, which can be used to evaluate responses (Table 2).

A pen torch should be used to check for symmetrical reactivity to light, spontaneous eye movements, pupil size, and symmetrical eyelid movements. A sluggish light response or dilation might mean intracranial injury on the side of the enlarged pupil, while impaired eye closure and blinking may mean damage to a cranial nerve. While the eyes are examined, it is useful to check the athlete's verbal responses and level of concussion by asking simple questions such as "What is your name?" More testing questions such as "What team are you playing?" will test short-term memory and also understanding. Formal assessment tools such as a Maddocks score (Table 3) and the Standardized Assessment of Concussion (SAC) can be used to elicit information about suspected concussion. A quick check of finger and toe movements will show if there is a deficit of motor function.

Neck injuries should be further assessed at this stage and a decision made about whether they require specialist medical care. A good rule to follow is that any athlete who is unwilling to spontaneously move his or her neck should be suspected of having a serious neck injury. If the athlete reports no pain and the suspicion of a serious neck injury is low, a screen for neck injury is to ask the athlete to very slowly raise his or her head off the ground voluntarily to touch the chin to the chest. If the index of suspicion for head and neck injury is high, then any movement should be avoided until the head and neck are cleared in an appropriate medical facility.

Table 2 Glasgow Coma Scale: A Tool for Assessment of a Patient With Reduced Consciousness

Eye opening	
Spontaneous	4
To voice	3
To pain	2
None	1
Verbal responses	
Oriented	5
Confused	4
Inappropriate words	3
Incomprehensible sounds	2
None	1
Motor response	
Obeys commands	6
Localizes to painful stimulus	5
Withdraws to painful stimulus	4
Flexion to painful stimulus	3
Extension to painful stimulus	2
None	1

Examination of the peripheral limbs for fractures and any other abnormalities forms part of the secondary survey. An examination of light touch and distal pulses can usually identify a serious problem early on the field.

How to Manage Disability

The most worrisome type of disability is head and neck injury, and if one is noted, it is important

Table 3 Maddocks Score: A Tool for Assessing an Athlete With Concussion

At what venue are we today?	0	1
Which half is it now?	0	1
Who scored last in this match?	0	1
What team did you play last week/match?	0	1
Did your team win the last game?	0	1
Maddocks score		Score = __ out of 5

Source: McCrory P, Meeuwisse W, Johnston K, et al. Consensus Statement on Concussion in Sport. Third International Conference on Concussion in Sport held in Zurich, November 2008. *Clin J Sport Med.* 2009;19(3):185–200.

Notes: Ask the patient to answer the following questions to the best of their ability. Give one point for each correct answer. This tool is validated for sideline diagnosis of concussion only.

to be on the lookout for the other. If there is any suspicion of these injuries, the patient should be immobilized and transferred to a spine board for further evaluation. Logrolling may need to be performed as discussed earlier (see pages 513–514). Extremity fractures may be splinted in a painless position to reduce tension as part of the primary survey, but reduction of fracture should only be undertaken by an experienced physician. Similarly, an obvious dislocation should be reduced only by a practitioner experienced in the procedure, as improper reduction can lead to nerve and vessel damage. Most problems identified during the disability step require urgent medical attention and further investigations.

E: *Exposure and Environment*

What to Look Out For

This step consists of making sure that any injuries have not been missed and planning on moving the athlete to a safe environment if he or she is stable. Any environmental dangers should also be looked for in terms of both the other athletes and the patient. If one athlete has succumbed to the environmental problem, then it is highly likely that others will too. The two major conditions to watch out for are hypothermia (low body temperature) and heat illnesses. Heat injuries are often underdiagnosed. Humidity can also play a part in causing heat-related illness. Athletes competing in particularly hot, humid climates are more susceptible to dehydration. Other environmental problems to watch for are lightning and rain. Lightning, although very rare, carries the threat of burns, mechanical damage from the high voltages passing through the body, and blunt trauma injuries from falling or propelled objects. A wet athlete can become cold rapidly and, if appropriate, should be covered when carrying out the primary survey.

How to Assess Exposure and Environment

An accurate measure of core body temperature can be difficult to obtain, as oral, external, and tympanic thermometers are not very reliable. Rectal temperature is still the best estimate of core temperature, though it is not always practical to measure on the field of play. Obvious signs of heat stroke are confusion, a decreased level of consciousness, and hot, dry skin. Dehydration may further complicate the picture, and the athlete will be acutely unwell. Early signs of this are decreased skin turgor (loss of skin elasticity) and dry mucous membranes, most noticeably in the mouth. Hypothermia can also occur along with dehydration but is most recognizable from a decreased level of consciousness combined with a cold, pale, cyanotic skin.

How to Manage Exposure and Environment

Heat- and cold-related injuries are covered in more detail elsewhere in the encyclopedia, but controlling the athlete's environment is still an important part of a primary survey. Obvious signs of heat- or cold-related injury should precipitate immediate transfer to a medical facility. While the primary survey is being carried out, it is not unreasonable to cover the athlete to keep him or her warm; however, care should be taken not to move the patient. In the case of a heat injury, any heavy clothing should be removed. The athlete should be cooled with water and ice, preferably in the shade. Ice water immersion appears to be the most practical means of reducing core temperature during a sports event. Dehydration can exacerbate both heat and cold injuries, and so fluid balance is an important part of treatment. Intravenous or oral fluids should be given to correct this and aid in temperature regulation. Dehydration can be a major contributory factor to hyperthermia, and though it is possible for heat injury to occur in well-hydrated athletes, this is unlikely. If a cold injury is suspected, then the patient's wet clothing should be removed and replaced with dry clothing and warm blankets. In the event of severe hypothermia, the athlete must be rewarmed slowly at a medical facility to avoid metabolic disorders, referred to as reperfusion injury.

Once the primary survey is completed and the athlete's immediate condition has been assessed, he or she can be triaged. Any abnormality found on primary survey usually requires emergency transfer. Otherwise, the secondary survey can be performed on the sidelines.

Emergency Transfer

Following the primary survey, the decision must be made about whether to activate the emergency protocols. If the athlete's condition is of concern, a call to activate the emergency services (911) should be made immediately for hospital transfer. Similarly, if the primary survey did not reveal an immediate life-threatening issue but the secondary survey reveals a serious problem, emergency transfer is needed. Ideally, patients will be assessed as soon as possible, and the level of transfer urgency is often determined by the emergency medical services. Suggestions for stabilizing the athlete and best options regarding the method of transfer, whether by ambulance or by air transport in a helicopter, should be considered if the athlete's arrival at an emergency center may be delayed. It is best to call the emergency center and provide as much information as possible to help them prepare for the injured athlete. Once the ambulance crew arrives, they often take the lead in preparing the athlete unless there are other individuals on site with more experience.

Prior to departure from the field, the patient's airway, breathing, and circulation should be stabilized as well as possible, and an attempt should be made to control hemorrhage. All face masks and obstructions to the airway should be removed before transfer, except the headgear, which causes no obstruction. A secure airway should be established before transfer commences.

If vertebral column or spinal cord injury is suspected, the patient should be transported to an appropriate trauma center. When moving the patient with a suspected spinal injury, the most important thing to remember is that the head and the spine must be moved as one. Generally, this will involve the head being repositioned to the neutral position for in-line immobilization. Using the technique described earlier in the entry, the patient should be logrolled and a spine board placed underneath. The neck can be secured to the spine board using either a rigid neck collar or, if needed, padded towels and sandbags. This should be done by paramedics if waiting is possible, unless there is a need to move the athlete immediately or provide resuscitation measures. Transfer of athletes with suspected spinal injuries should not be done in a private vehicle and should always be carried out by emergency medical staff with the assistance of athletic trainers and team medical staff.

Secondary Survey

The secondary survey ideally should be carried out in a comfortable, controlled environment away from any further exposure, preferably indoors. It usually involves a detailed, systematic assessment from head to toe to find any non–life-threatening conditions that were not detected immediately.

History

The history should include specific details regarding any concerning conditions. More general information regarding the athlete's overall health should be elicited, for example, age, medication use, allergies, past medical history/pregnancy, last meal, and the events preceding the injury. A thorough history of the injury can help the practitioner make decisions about the athlete's management plan as well as return to play, withdrawal from play, or transfer to a medical facility.

Examination

The patient should then be examined from top to toe, starting at the head, looking for obvious lacerations or deformity and signs of underlying injury.

Moving methodically down the spine and neck to the chest, abdomen, and limbs, the examining physician should look at each organ system, including the respiratory, cardiac, abdominal, renal, and neurologic systems, thoroughly before any decision about return to play is made. The detailed examination of any affected joints or limbs and organ systems is explained in other entries of this encyclopedia.

First Aid

The approach to first aid should be dictated by both the outcome of the primary and secondary surveys and common sense. It is vital that the physician recognize his or her limitations with regard to skills and resources, but if appropriate, the physician may decide to manage problems on site at the event. This should be accompanied by early follow-up and notification of relevant support services. A good understanding among all members of the medical team will help direct the care of the athlete more cohesively and allow good agreement over return-to-play decisions.

Procedures that the physician may consider performing on site are taping injured joints, splinting fractured limbs or joints, applying pressure bandages, and simple measures such as applying ice to bruises and new injuries. The physician should be comfortable with basic therapies in early treatment of sports injuries, such as massaging, stretching, ice application, and rehabilitation exercises for injuries such as sprains and strains.

Immobilization and Splinting

If a fracture is suspected or there is considerable damage to a joint or bone, splinting must be considered to protect the area and prevent further damage. For the lower extremity, a splint or leg immobilizer can be applied, while a sling or splint is used to immobilize the upper extremity.

Joint Dislocation and Reduction

A dislocated joint is often more easily relocated immediately after an injury, before any soft tissue swelling occurs and muscle spasm tightens around the joint itself. The shoulder is the most commonly dislocated large joint, with dislocation of the fingers, hips, elbows, and knees also possible. Many techniques have been described to relocate a dislocated shoulder, mainly dealing with the common anterior dislocation. In the right hand, an immediate reduction maneuver is a highly effective treatment. There are significant dangers in poorly conducted relocation, such as displacement of fractures and neurovascular injury. Reduction should only be undertaken by experienced professionals and should not be attempted repeatedly as complications can occur, such as soft tissues catching in the joint. Prompt medical evaluation is still needed even following a successful reduction of the joint to properly assess for any underlying damage. Dislocations are often accompanied by ligament injury and fracture.

Wound Care

It is valuable for the sports practitioner to know the basics of proper wound care. The well-prepared fieldside physician will bring supplies to clean, sterilize, and close wounds. Oftentimes, normal saline or water can clean most wounds, though many antiseptic cleansing solutions are available. Before any attempt at closure is made, the wound must be thoroughly cleaned and debrided of all tissue at the edges of the wound. All foreign objects should be removed, and the wound should be thoroughly irrigated with normal saline. Very dirty wounds should be left open until they can be treated at a medical facility, as closure can carry a high risk of infection. Immunization status is another area where mistakes can be made as an out-of-date tetanus status can make small lacerations much more serious.

A local anesthetic can be used on the skin to reduce sensation in a painful wound. Sutures, staples or sterile adhesive strips, and/or proper wound dressing and bandaging techniques can be used to close small wounds effectively. Large lacerations should receive firm pressure and wound dressing to stop or at least slow any bleeding and usually require transfer to a medical facility for closure. Care should be taken to avoid bandaging a wound too tightly to avoid any compromise of distal blood flow to a limb, in case transfer will be delayed by more than 2 hours.

Eye, Teeth, and Facial Injuries

Particular care should be taken with these types of injuries as players can be tempted to continue to play when it is really not advisable to do so. Eye injuries generally fall into the categories of blunt trauma, corneal abrasions, and penetrating wounds. All these can produce lasting damage, and it is highly recommended to seek expert help at the earliest. While emergency transfer is not warranted, removal from play and referral to an ophthalmologist are recommended in all but the most minor of injuries.

Return to Sports

Effective management of minor problems can take place after major problems are ruled out in the primary and secondary surveys. If the athlete has been through these stages and the injury seems minor, the player can be assessed for return to play. It is perhaps the most challenging decision to make for sports physicians, as their own clinical intuition and caution must be tempered against the will of athletes and coaches to carry on. All members of the medical team should communicate their input regarding the athlete's status to the lead individual to make a decision for safe return to play.

For immediate return to play in the case of minor injury, the physician decides whether the athlete will be safe from further injury. If so, the return to play can be discussed with the coaches, athletes, and other involved parties as to whether the player is able to compete effectively and be painfree. Risk of reinjury will be an absolute contraindication to continuing play, and this must be assessed based on the physician's knowledge of the condition. If the athlete can safely play with his or her injury and there is no risk of reinjury, this must be balanced against how effective the athlete will be on return to play. To gain further insight into the effectiveness of the player, it is common to put the athlete through a series of drills specific to his or her sport. If the athlete experiences pain, then it is common to withdraw him or her from play. However, if the athlete completes the tasks well, then play can be recommenced at the physician's and coach's discretion.

Anthony Gibson and Anthony Luke

See also Craniofacial Injuries; Dehydration; Dental Injuries; Eye Injuries; Fractures; Head Injuries; Shoulder Dislocation; Spinal Cord Injury; Taping

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Figure Skating, Injuries in

From its historical origins as a mode of transportation, ice skating has developed into figure skating, a popular sport that combines the highest levels of artistry and athleticism. Mastery of figure skating requires years of practice and continual repetition of skills. Injuries in figure skating are most commonly of the overuse type, largely due to this constant repetition. Acute injuries are less common but certainly do occur as a result of falls, collisions, and errors in the execution of skills.

There are four disciplines in figure skating that the athlete may pursue once the basic skating skills have been developed. First, singles skaters perform multirevolution jumps, spins, step sequences, and edge moves. The second group, pair teams,

Professional figure skaters performing at a "Stars on Ice" show

Source: Can Stock Photo.

consists of a male and a female skater performing all the same moves as the singles skater with additional high-risk skills of overhead lifts and throw jumps. In the third group, male and female skaters can join to form a dance couple. The required skating skills performed in ice dance emphasize quality edges in intricate step sequences and precise body positions to a specific dance rhythm with limitations on spins, lifts, and jumps. Synchronized skating is the fourth and fastest-growing discipline in figure skating. Teams of 16 skaters perform together and are required to do quality edges in intricate step sequences, creating specified formations on the ice. The skaters connect through various arm holds and may also intersect the formations with one another. At the advanced levels, teams perform spins, single-revolution jumps, and lifts under specified limitations.

Contributing Factors for Injuries

More than half of all skating injuries are the result of overuse. The ankle and foot are often involved, with increasing hip, pelvis, and spine injuries occurring as the level of difficulty in skating moves increases at younger ages. Injuries to skaters occur frequently because of their equipment, the boot and blade. Evaluating the fit of the boot and alignment of the foot in the skate can be important in assessing the cause of injury.

Overuse injuries in sports typically result at least in part from lack of flexibility and asymmetry of strength, and skaters are no exception. Additionally, the skater must have correct spinal and body alignment to properly balance on the ice. Issues of flexibility and strength therefore are crucial to the skater maintaining proper alignment and, thus, balance while skating.

Foot

Malleolar bursitis develops with excessive pressure and shear force stress between either the medial or lateral malleous and the boot, creating inflammation and at times significant swelling. This condition often occurs if the boots are breaking down and not providing adequate support. It may also develop as a skater is breaking in a new pair of boots. The goal of treatment is accommodating the boot to the skater's foot. The boot can be stretched or punched out over the malleoli. Doughnut padding with a compressible foam material can also be useful. Aspiration and cortisone injection are typically not beneficial. In rare instances, surgery may be necessary.

"Pump bump," or the Haglund deformity of the calcaneal tuberosity, results from improper fit of the skater's heel in the boot. A loose fit causes the heel to slide up and down in the skate, creating friction, whereas a fit too tight can cause compression. Padding and heel lifts can usually help achieve proper heel fit.

The anterior aspect of the ankle is subject to excessive compression from the tightened laces and creases in the tongue of the boot, causing what is commonly referred to as "lace bite." Tendinitis over the front of the ankle can occur from these boot factors combined with the repetitive bending at the ankle and pointing of the foot. Skin irritation can also develop, and skaters commonly develop a protective callus over the anterior ankle. Proper positioning of the boot tongue and protective padding can alleviate these issues.

Repetitive stress due to bending of the ankle in the boots, along with the loading of jumps and landings, subjects the posterior ankle to potential overuse as well. Achilles tendinitis can result from chronic compression if the boot is too high at the back of the ankle. The boot may be modified by creating a cutout area for the Achilles tendon. Poor flexibility in the Achilles combined with the repetitive plantarflexion during skating push-offs may also contribute to Achilles tendinitis. The posterior tibialis medially and the peroneal muscles laterally work to maintain balance, which may subject them to boot compression or overuse including shin splints. Ongoing and repetitive stress to these structures of the foot, ankle, and lower leg has the potential to lead to stress fractures as well. A thorough assessment of the strength and flexibility of muscle/tendon structures about the ankle is imperative. Careful examination of the boot, blade position, and the skater's foot position in the boot should be done for their contribution to abnormal stress production.

Knee Injuries

Knee injuries in skaters are also typically due to overuse. Acute ligament or meniscus injuries do occur, but less frequently. Since the blade is not fixed to the ice, the characteristic mechanism of an ACL (anterior cruciate ligament) injury of planting the foot and then rotating is more difficult to accomplish on the ice.

Anterior knee pain occurs frequently in the skater as a result of the physical demand on the extensor mechanism of the knee. Jump takeoffs and landings produce significant forces on the quadriceps muscle and extensor structures. Falls may produce contusions to the patella, but fracture is rare. Patellar tendonitis is common and again related to the stress placed on the patellofemoral extensor mechanism. Skaters frequently demonstrate tightness of the quadriceps, hamstrings, and hip flexor muscle groups, along with asymmetry of muscle strength of the hip and thigh from one side to the other or anterior to posterior.

Hip and Groin Injuries

The issue of flexibility and strength of the hip and thigh musculature also increases the risk of groin and hip flexor injuries in the skater. The focus on mastering triple and quadruple multirevolution jumps at younger ages has led to an estimated 25% increase in these injuries among elite skating competitors. Skaters may perform 50 or 60 repetitions of a given jump during a day's practice in an attempt to perfect the execution of the jump. Clearly, overuse strains are a potential problem. Many falls and fumbled attempts occur in the practice of jumps, which can produce more acute injuries such as an avulsion fracture of the ischium or iliac crest. The skeletally immature skater in a growth spurt is especially vulnerable to such an injury. As in other sports, these injuries can be difficult to manage and slow to heal. Focus on proper flexibility, strength, and avoiding excessive repetition plays a critical role in preventing these injuries.

Spine

The spine sustains significant stress during jump landings and several extension moves performed in figure skating. Stress on the posterior elements of the spine is further increased if correct spinal alignment is not achieved and maintained during execution of these moves. Tightness of the hip flexors along with weakness of the lower abdominal core muscles necessitates a hyperlordotic ("sway back") posture to maintain balance. This creates compression and stress on the posterior elements during the hyperextension of the layback spin (extending or leaning backward) or the Bielman position (extending backward while pulling one leg over the head in a U shape). Jump landings occur onto a backward skating edge and can generate a quick hyperextension as the skater regains contact with the ice. If the skater is in a more lordotic posture with weakness in the lower abdominal muscles, he or she will land the jump with the body forward of the center of gravity. To remain upright, the skater must quickly extend the back to regain balance.

Causes of back pain in the skater may include lumbar muscle strains, facet joint sprains, apophysitis (inflammation of tendon attachments to bone), or spondylolysis (stress fractures) of the spine. The development of spondylolysis in skaters is common. Any skater with persistent back pain, especially with extension, should be tested for spondylolysis. X-rays are not very sensitive in identifying this problem; therefore, evaluation with a bone scan is recommended. Further exam with computed tomography (CT) scan or magnetic resonance imaging (MRI) may be necessary. Treatment for spondylolysis includes rest, physical therapy for core strengthening, and possibly bracing.

Upper Body

Injuries of the upper extremities usually occur in paired, dance, and synchronized skaters. Acute injuries such as ligament sprains or shoulder dislocations can develop from missed lifts and falls or errors in partner positions and holds. With synchronized skaters, the repetitive holds may lead to overuse injuries, typically of the rotator cuff and wrist.

Skaters are also at risk for head injuries. Falls, especially from lifts and collisions on the ice, are typically responsible. In synchronized skating, with 16 skaters on the ice and skating closely together, even small errors in position could result in collision and "pileups" on the ice, with risk of head injuries and also lacerations from skate blades.

Ellen Geminiani

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Finger Dislocation

A *finger dislocation* is an abnormal alignment of the bones of a finger. Due to injury, the bones separate, and one of them moves out from its normal position in the joint. Therefore, the joint's articulating surfaces no longer touch each other, whereas finger subluxation occurs when the loss of continuity between the joint's articulating surfaces is only partial: The bones lose their normal relationship but still touch each other.

Finger dislocation is a common hand injury in athletes. Several sports have been associated with finger dislocations: American and Canadian football, basketball, lacrosse, ice hockey, water polo, cheerleading, rodeo, handball, and volleyball are some among them. Among martial sports, whose practitioners are particularly exposed to finger dislocations, can be cited judo, jujitsu, aikido, wrestling, boxing, tae kwon do, kickboxing, karate, kung fu, and mixed martial arts.

Anatomy

In each finger, there are three bones, called *phalanges*: (1) the *distal phalanx,* which is located furthest from the wrist; (2) the *middle phalanx;* and (3) the *proximal phalanx*. The thumb contains only two phalanges: the proximal and the distal phalanx. Each proximal phalanx is joined to a specific metacarpal bone, one of the five bones that compose the middle part of the hand. Bones are linked to each other in joints: Finger dislocation may involve either the joint between two phalanges, which is called the *interphalangeal joint,* or the joint between the proximal phalanx and the metacarpal bone, which is called the *metacarpophalangeal joint* (see Figure 1).

Around the joints, there are ligaments and tendons. These structures stabilize the joint, holding the bones together, and allow the muscles to perform their movements. Ligaments are bundles of

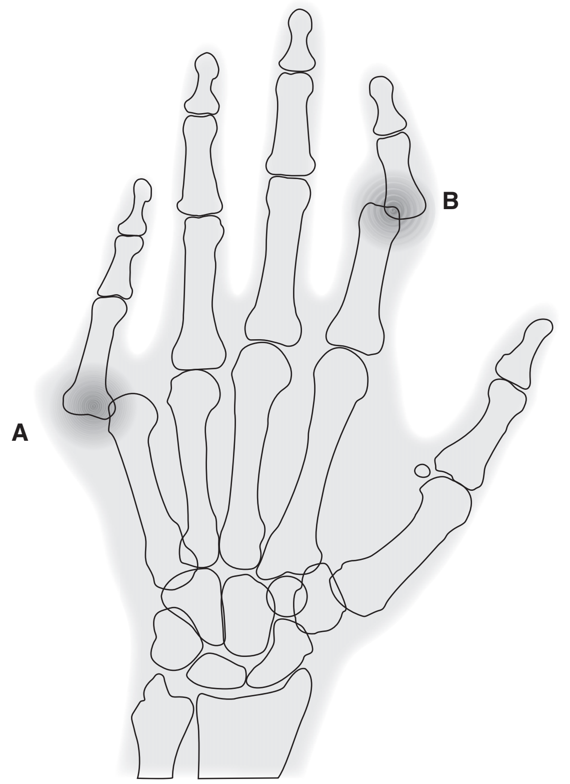

Figure 1 Finger Dislocations: A = Metacarpophalangeal Joint; B = Interphalangeal Joint

fibrous tissue that connect the extremities of different bones. In the hand, each interphalangeal and metacarpophalangeal joint is supported by the volar plate, which forms the floor of the joint, and two collateral ligaments. Tendons are ropelike structures that attach the muscle to the ends of one or more bones. Also, tendons lend further support to joints.

Injuries that cause bone misalignment can also provoke damage to ligaments and tendons. In fact, when bones lose their normal joint position, ligaments may disconnect from their attachment or tear, and tendons may suffer strains and tears. These injuries can cause further joint instability. Moreover, other soft tissues that surround the dislocation site may suffer damage, among them the muscles, periosteum (the tissue that covers the bones), nerves, blood vessels, and connective tissues.

Causes

Sports are among the most common causes of dislocations. A finger dislocation can result from falls and all accidents in which fingers are trapped between objects (e.g., equipment, such as helmets and pads), twisted sideways, and/or forced to hyperextension or hyperflexion. *Hyperextension* is a movement that extends the angle between the bones of a joint, so that this angle becomes greater than normal. For instance, this may occur when an athlete tries to catch a ball with his or her fingertips. On the contrary, *hyperflexion* is a movement that decreases the angle between the bones of a joint, so that this angle becomes smaller than normal. These events occur frequently in sports and especially in martial sports. Dislocations may occur in predisposed athletes even in the absence of severe trauma: Such a predisposition is shown by participants whose ligaments are looser than normal—for instance, those who suffer from congenital ligamentous laxity.

Symptoms

The patient experiences intense pain immediately, at the time of injury, and later, when he or she attempts to move the injured finger. Within a short time following the injury, the dislocated finger swells: Blood flows from the torn blood vessels into the dislocated joint and accumulates. Usually, the dislocated finger appears misaligned or awkwardly bent, but in some cases the deformity may be obscured by the swelling. The injured joint may suffer a loss of function (which results in a limited range of motion of the affected finger) and/or a loss of stability (which results in an abnormal range of motion of the affected finger). If nerves are pressed, pinched, or cut, numbness, tingling, hypoesthesia, or dysesthesia may result in the involved finger below the dislocation.

Diagnostic Tests

To diagnose a finger dislocation, the physician requests information about the history of the injury and makes an initial physical examination. After musculoskeletal and neurovascular evaluation, the physician may order X-ray films from different angles to confirm the dislocation hypothesis and/or detect possible fractures. Imaging studies are repeated after reduction to assess the repositioning of the dislocated bone. After 2 weeks, magnetic resonance imaging (MRI) and/or ultrasound imaging may be required to evaluate the healing process. After some weeks, stress tests will be performed to evaluate joint stability.

Treatment

On-Field Treatment

During on-field evaluation and management, the finger should be elevated at or above heart level, and an ice compress should be applied to reduce swelling and pain. If there are skin lacerations, irrigation must be performed to clean the wounds. Rings should be removed immediately. Medical care should be sought as soon as possible, because delaying treatment increases the risk of permanent damage to the affected joint.

Nonsurgical Treatment

In many cases, a closed reduction can correct the dislocation. This occurs when the physician moves the misaligned bones to put them back in proper position. After evaluating joint stability/instability, the doctor wraps loosely a dry gauze around the injured finger to improve grip. Then, he or she grasps the dislocated finger and makes appropriate motions with the aim of removing the bone extremity from the wrong position and gradually pushing the displaced phalanx into its correct anatomical position. All the motions made for reduction are accomplished gradually and gently, because violent maneuvers may cause permanent injury. After reduction, the physician examines the neurovascular status, the tendon function, the phalanges' range of motion, and the joint's stability. Then, he or she immobilizes the joint with a splint to prevent instability or redislocation. As a general rule, the splint can be removed after 2 to 3 weeks; thereafter, the dislocated finger can be "buddy taped" for 3 to 4 weeks. This technique, in which the injured finger is taped to an adjacent finger above and below the dislocated joint, prevents hyperextension but allows, however, active range of motion (see Appendix A for further information on buddy taping).

Surgery

In some cases, finger dislocations require surgery, for instance, if there is a severe injury to ligaments or tendons, so that these structures need to be repaired. Moreover, it may be necessary to perform an open (surgical) reduction if the injury has caused a dislocation of the volar plate, ligaments, and/or tendons, which could prevent the correct repositioning of the joint bones. If the finger dislocation is an old one, it may be necessary to remove the scar tissue that could have formed after the injury. Finally, operative reduction may be necessary if the joint, though restored to its normal position by a closed reduction, is nonetheless not yet stable. As a general rule, the hand surgeon will expose the joint by means of one or more incisions; then, he or she will reduce the joint and repair the damaged structures. Finally, the surgeon will close the incisions by suture.

Medications

A finger dislocation and the following reduction may be very painful; therefore, the physician may prescribe drugs to relieve the pain, such as analgesics or even narcotic pain relievers. Anesthesia is usually given: local anesthesia in the case of a closed reduction and general anesthesia if surgery is necessary. If there are open wounds and/or a surgical reduction has been performed, antibiotics are prescribed to prevent/fight infections.

Prognosis

The long-term prognosis for finger dislocation is good. However, pain and/or swelling may persist for some months. There is a high risk of recurrent dislocations of the affected joint. This can be due to the damage to the ligament and/or inadequate immobilization of the affected joint after reduction. Delayed reduction may cause loss of joint motion and, thus, limitation of hand function.

Rehabilitation and Return to Sports

When the supportive wrapping can be removed, rehabilitation can begin. The injured area should be massaged with ice before and after a workout. Rehabilitation exercises should be individualized; yet simple activities, aimed at improving the active and passive motions of the injured finger (such as slowly squeezing a tennis ball or extending the fingers), are generally recommended. The athlete can return to sports when the injured finger has regained its full range of motion; however, rehabilitation exercises should be performed even after that date. For several weeks, use of taping during sports may be recommended.

Prevention

Primary prevention involves using protective devices or tapes. Secondary prevention can be carried out by stretching and strengthening the muscles that surround the injured joint.

Alessandra Padula

See also Finger Sprain; Hand and Finger Injuries; Hand and Finger Injuries, Surgery for; Jersey Finger; Mallet Finger; Taping; Thumb Sprain; Trigger Finger

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Finger Fractures: Bennett Fracture, Boxer's Fracture

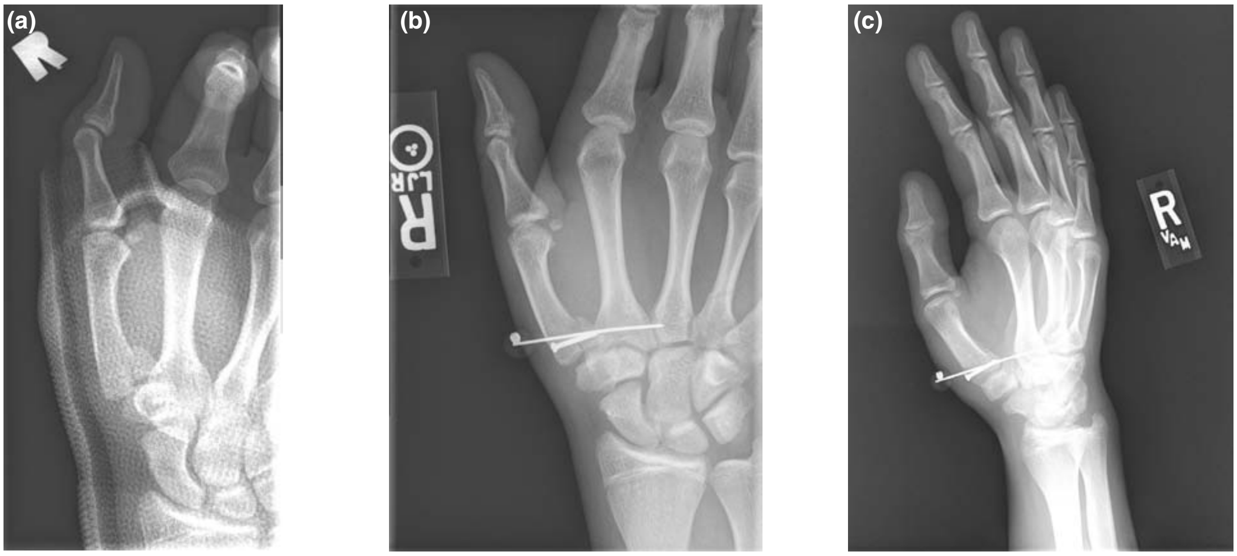
Bennett Fracture

The Bennett fracture, first described by Edward Hallaran Bennett in 1882, is a two-part fracture/subluxation (or dislocation) of the base of the thumb metacarpal involving the volar (palmar) articular surface. This fracture type represents approximately 30% of all thumb metacarpal fractures and occurs when the thumb metacarpal is partially flexed and axially loaded. These are relatively common sports injuries.

Although the fracture fragment can vary in size, it always consists of the volar ulnar aspect of the metacarpal base. The abductor pollicis longus (APL) acts as a deforming force and may displace the metacarpal base proximally, dorsally, and radially and tends to supinate the metacarpal shaft. The adductor pollicis, in contrast, may adduct the metacarpal shaft. The intraarticular volar ulnar fragment is held in a constant position via its attachment to the anterior oblique ("beak") ligament that inserts onto the trapezium. The base of the thumb metacarpal articulates with the trapezium, forming the basilar joint or thumb carpometacarpal (CMC) joint. Axial rotation of the joint is limited by the joint capsule, the ligaments, the extrinsic tendons, and the geometry of the articular surface. The articulation of the thumb metacarpal and the trapezium resemble two interlocking saddles, allowing motion in both flexion-extension and abduction-adduction planes. If Bennett fractures go on to a malunion, posttraumatic thumb CMC joint arthritis will likely develop. The goal of treatment, therefore, be it nonoperative or operative, is to achieve the best articular congruity and stability possible at the thumb CMC joint.

Closed reduction of a displaced Bennett fracture/dislocation should be attempted by applying longitudinal traction on the end of the thumb, coupled with abduction, extension, and pronation of the metacarpal shaft. Manual pressure on the base of the metacarpal may prove to be helpful. If adequate reduction is unobtainable via closed means or is obtainable but is unable to be held over the course of several weeks, surgery may be necessary to ensure articular congruity. Cast immobilization of this fracture pattern has the benefit of avoiding surgical infection risk but is sometimes problematic as it can be difficult to maintain adequate three-point fixation over the thumb metacarpal and to maintain this contact pressure once swelling has subsided. The literature demonstrates poor outcomes if these fractures are treated 4 or more days after injury with cast immobilization. Long-term studies of patients treated nonoperatively for Bennett fractures reveal a high incidence of symptomatic arthritis, with impaired mobility and decreased strength.

Acceptable surgical treatment options include closed-reduction percutaneous pinning (CRPP), open-reduction internal fixation (ORIF), and external fixation. Two percutaneous pinning methods are commonly used for treatment of this fracture pattern. The first is intermetacarpal pinning, where two Kirschner wires are used to hold the thumb metacarpal to the index finger metacarpal. The second pinning option involves placement of a Kirschner wire down the shaft of the thumb metacarpal and through the first CMC joint. If open reduction is required to obtain articular alignment, fixation can be achieved in a number of ways. If the Bennett fragment is large enough, a screw can be used to obtain compression across the fracture site. Similarly, a plate and screws can be used to hold the Bennett fragment to the metacarpal shaft. Instead of using internal fixation, two Kirschner wires can be used to secure the metacarpal shaft to the constant fragment. The wires can be buried under the skin or left exposed and then removed at a later date. If pins are used for fixation, the thumb is immobilized in a thumb spica cast. Trans-CMC joint pins are usually removed 4 weeks after surgery, and fracture fragment pins are usually



(a) Posteroanterior (PA) radiograph of a displaced Bennett fracture that presented to the office 4 weeks after injury. There was a notable intraarticular step-off at the thumb CMC joint. (b) Posteroanterior (PA) view. (c) Oblique radiographs of this fracture postoperatively treated with an interfragmentary compression screw and a Kirschner wire traversing the first and second metacarpal bases.

Source: Photos courtesy of Craig M. Rodner, M.D.

removed 4 to 6 weeks after surgery. Active range of motion can be started relatively sooner postoperatively if screw fixation is used than if pins are used. Image (a) above demonstrates a radiograph of a displaced Bennett fracture that was presented to the office of one of the authors (C.R.) 4 weeks after injury. Images (b) and (c) show the postoperative radiographs of this fracture after an ORIF using both interfragmentary compression and a temporary Kirschner wire traversing the first and second metacarpal bases.

Although nonunion of a Bennett fracture is exceedingly rare, malunion of these fractures is not uncommon and can result in persistent thumb CMC subluxation. A closing-wedge osteotomy at the base of the thumb metacarpal has been described to correct instability following malunion of a Bennett fracture more than 6 weeks postinjury. Patients with long-standing instability and/or arthritis following a Bennett fracture/subluxation malunion may benefit from a salvage procedure such as arthroplasty or arthrodesis of the thumb CMC joint.

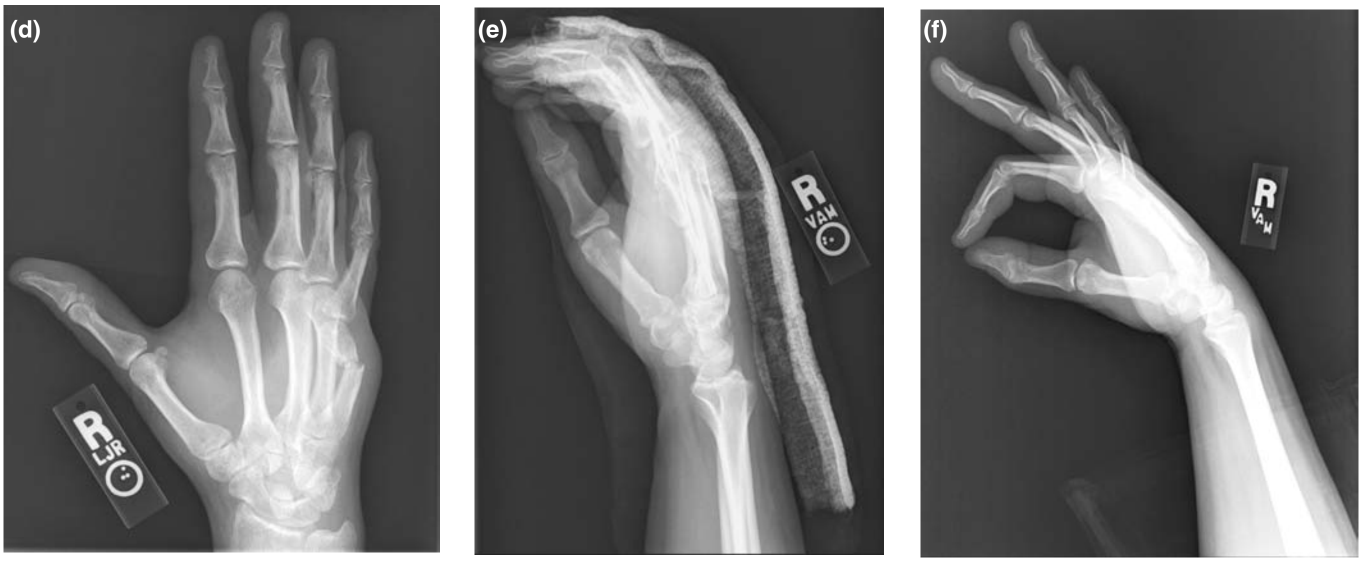
Boxer's Fracture

The term *boxer's fracture* typically describes a fracture through the metacarpal neck of the small finger, but in fact, it can be used to describe a metacarpal neck fracture of any digit. A boxer's fracture of the small finger is really a misnomer, because boxers rarely suffer from this type of injury. A small finger metacarpal neck fracture is more commonly seen in brawlers and in people who hit solid objects such as walls.

The metacarpal neck represents the weakest portion of the metacarpal and commonly is fractured when a clenched metacarpophalangeal (MCP) joint strikes a solid object. The volar aspect of the fracture is affected because the impact occurs on the dorsum of the metacarpal head. As such, the fracture typically has an apex dorsal deformity because the pull of the intrinsic muscles lies volar to the axis of rotation and maintains the flexed metacarpal head posture (see image d, page 528). The metacarpal head tends to displace volarly and proximally. Excess volar proximal displacement leads to an imbalance of the extrinsic tendons and results in a claw deformity. Nonunion of boxer's fractures virtually never occurs, but malunion is a relatively common occurrence. Patients may complain of loss of prominence of the metacarpal head, decreased range of motion, a palpable metacarpal head in the palm, and possible rotatory malalignment.

Several factors help determine the treatment algorithm for these fractures. First, it is necessary to focus on which metacarpal is involved and, second, to assess the degree of angulation. Third, it is important to determine if there is any rotational deformity present. An acceptable volar angulation for these fractures is approximately 40° to 50° for the small finger, 30° to 40° for the ring finger, 20° for the middle finger, and 10° for the index finger. The ring and small fingers have approximately 20° to 30° of laxity in the sagittal plane, and therefore, more angulation may be tolerated in these digits. The index and middle finger CMC joints have less mobility in the sagittal plane, so rotation cannot be compensated for as well.

When performing a closed reduction of a boxer's fracture, the Jahss maneuver can be used. This maneuver involves flexing the affected digit to 90° at the MCP joint, which causes the intrinsic muscles to relax and the collateral ligaments to tighten. An upward dorsal force is then applied to the head of the proximal phalanx at the proximal interphalangeal (PIP) joint, and a downward volar force is applied to the metacarpal proximal to the fracture site. Once the metacarpal neck is reduced, the fracture can be splinted in an intrinsic plus position (wrist extension, MCP flexion) with an ulnar gutter splint for approximately 2 to 3 weeks. If the small finger is the affected digit, it should never be immobilized in the Jahss position (MCP and PIP joints flexed at 90°) following closed reduction. Several prospective studies have been performed comparing splinting, functional bracing, and elastic bandaging after closed reduction. Although there was no difference with regard to patient satisfaction among the three treatment groups, those patients who underwent functional bracing became mobile faster and experienced less pain.



(d) Oblique radiograph of a displaced boxer's fracture with typical apex dorsal deformity; (e) Lateral radiograph of a boxer's fracture treated with two intramedullary Kirschner wires; (f) Lateral radiograph of a boxer's fracture treated with a dorsal plate and screws

Source: Photos courtesy of Craig M. Rodner, M.D.

If surgery is necessary for a boxer's fracture, the treatment options are similar to those described for Bennett fracture. If reduction can be achieved by a closed technique, the fracture may be pinned by two intersecting Kirschner wires placed within the shaft of the metacarpal (image (e), page 528), or transversely through the fracture fragment to the adjacent metacparpal. The disadvantage of pinning these fractures is that Kirschner wires do not provide rigid fixation and some form of external immobilization is usually necessary. Open reduction of boxer's fractures is indicated when closed manipulation fails to restore an acceptable angulation or rotational alignment. Once the fracture site is opened and the metacarpal neck reduced, the fracture can be secured with Kirschner wires or a plate and screws (image (f), page 528).

If a patient presents with a malunion of a boxer's fracture, an osteotomy can be considered to correct the malalignment if the patient desires.

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Finger Fractures: Overview

Phalangeal fractures are common causes of sports-related morbidity. Ball-handling sports, particularly football and basketball, pose the greatest risk. A study of all sports-related hand injuries showed that 71% were fractures and 4% were dislocations. In a recent U.K. study surveying hand fractures sustained during sport activities, 54.1% of fractures were to the phalanges, most commonly the fourth and fifth digits. Young athletes are particularly susceptible to these injuries, with 22.4% of all finger injuries being sports related. The 10- to 19-year-old age-group is the most affected group. Historically, nearly a third of high school football injuries are sustained in the hand.

Clinical Evaluation

As with other injuries, a basic history of the incident provides essential information for diagnosis, treatment, and prognosis. The mechanism of injury will suggest not only the location of injury but also an approximation of the amount of force applied. For example, if a substantial amount of axial force is responsible, simultaneous injury to more proximal structures, such as the carpus or elbow, should be suspected.

General physical examination of the area will likely reveal edema (swelling), ecchymosis (bruising), and tenderness of the affected area. Range of motion and sensation of the affected digit may be decreased. Examining for associated soft tissue injury to collateral ligaments, tendons, blood vessels, and nerves is essential. Stability and stress testing are important for functional assessment immediately after the injury, postreduction if necessary, and throughout the treatment process.

Initial radiographic evaluation of any hand injury should include a minimum of three views. The most revealing radiographs for suspected phalangeal injuries are postero-anterior (PA) and lateral views of the specific digit, centered on the proximal interphalangeal (PIP) joint. If an open wound is present, radiographs can also be used to identify a foreign body, but further imaging, such as ultrasound (US), computed tomography (CT), or magnetic resonance imaging (MRI), may be necessary.

While the orthopedic trauma association provides a detailed classification scheme, fractures can generally be described in terms of location (head, neck, shaft, base physeal) and direction (transverse, spiral, and oblique, comminuted). They should also be classified as open or closed and stable or unstable. Determining these fracture characteristics will guide treatment and prognosis.

Basic Treatment

Most fractures do not require surgery and can be treated with closed reduction and splinting. "Buddy taping" is ideal for nondisplaced and impacted transverse fractures because it involves using an unaffected, adjacent finger as a splint (see Appendix A for further information). Closed reduction of phalanx fractures can be done by anesthetizing with a digital nerve block and approximating the proximal and distal fragments. Reduction is followed by splinting with the metacarpophalangeal (MCP) joint flexed to 90° and the interphalangeal (IP) joint fully extended. Postreduction assessment should evaluate rotation, stability, and strength. Two ways to assess for malrotation are to view all the digits in an end-on position for parallel nail plates and when fully flexed into the palm for signs of overlap. Fractures that are not stable after closed reduction have to be surgically corrected.

Surgery is indicated for phalanx fractures that are unstable, have severe injury to soft tissue structures, are rotationally deformed, or have intra-articular displacement. The following are specific evaluation and treatment considerations for individual phalangeal segments.

Proximal Phalanx

Shaft fractures are more common in adults, and subcondylar and neck fractures occur more often in children. Comminuted or transverse fractures generally result from direct trauma to the proximal phalanx, while spiral or oblique fractures arise from twisting injuries. It is essential to examine both the patient and the radiographs for signs of malrotation and angulation, as both can lead to significant morbidity.

The pull of intrinsic muscles usually pull transverse and short oblique fractures apex volar. However, long oblique and spiral fractures tend to rotate and shorten. Generally, the proximal fragment is held in a flexed position by intrinsic muscles, and the distal fragment becomes extended secondary to extrinsic forces.

Addressing treatment options for each type of fracture depends on its inherent stability and potential complications. Nondisplaced shaft fractures can be treated with immobilization alone. Most minimally displaced stable fractures and reducible stable fractures can be treated nonoperatively. Treatment involves splinting or buddy taping, with some fractures requiring up to 6 weeks to attain full healing.

Generally, a fracture that is not in satisfactory alignment after a closed reduction requires surgery. There are several types of fractures that always require surgery. Spiral-oblique fractures are always considered unstable and require internal fixation. Because even minimally displaced condylar fractures can lead to incongruity, angular displacement, or malrotation, they must be treated surgically. Variants of the subcondylar fractures that involve volar plate entrapment in the joint also require surgical treatment. Fracture dislocations involving greater than 40% of the articular surface often require surgical intervention. Finally, base fractures are most likely to be associated with soft tissue injuries such as extensor tendon, collateral ligament, and volar plate damage, which may require surgical correction.

Middle Phalanx

The middle phalanx is structurally unique because the central slip inserts dorsally and the flexor digitorum superficialis (FDS) inserts volarly. They exert deforming forces onto the fractured middle phalanx fragments. As a result of the pull of the FDS, the proximal fragment of a neck fracture often becomes flexed and creates volar angulation. In comparison, base fractures are affected by central slip extension forces on the proximal fragment and FDS flexion forces on the distal fragment, which create dorsal angulation.

Base fractures require special attention as they can be most functionally devastating. Volar base fractures can result in subluxations in the sagittal plane. The amount of articular surface involved determines the inherent stability of the fracture. Fractures with greater than 40% articular involvement usually require surgical intervention. Otherwise, they can be treated with extension block splinting. Dorsal base fractures can disrupt the integrity of the central slip and result in boutonniere deformity. They can also be accompanied by PIP dislocations. If the fracture is displaced, surgical fixation may be necessary.

Pilon fractures refer to a comminuted metaphyseal and articular surface that causes inherent instability. These fractures have been treated with open reduction and internal fixation, and now, alternatively, are treated with dynamic traction. Anatomic restoration of PIP articular contour is often not achieved, regardless of technique. Open reduction should be approached cautiously and may result in significant complications. Dynamic traction has become the treatment of choice. Complications of pilon fractures include arthrofibrosis or posttraumatic arthritis.

Distal Phalanx

The distal phalanx is anatomically distinct because it contains a tuft region and supports the nail apparatus. Crushing injuries to this region often result in nail bed injuries that can vary from a subungal hematoma to a nail avulsion and entrapment in the fracture site. These soft tissue injuries must be addressed to avoid deformity or nonunion.

The base of the distal phalanx is also the site of insertion for flexor and extensor tendons. While fractures to the volar and dorsal base are less common than fractures in other regions, they are the most unstable and may be associated with tendon avulsions. Most tuft and nondisplaced fractures can be treated nonoperatively.

Physical Therapy

Relying on radiographs alone can delay treatment progression, as clinical improvement often precedes radiographic union. Although the duration of splinting can be determined by patient symptoms, immobilization for longer than 3 weeks is associated with a poor outcome. Range-of-motion exercises for all unaffected digits should commence immediately after the injury and for the affected digit, once it is clinically healed.

Complications

The most common complication of phalangeal fractures is stiffness, and the most effective prevention is with early, protected motion. Stiffness occurs most often when a joint is involved and in post–open reduction internal fixation (ORIF) patients with comminuted and open fractures. While malunion of the fracture fragments may lead to deformity, stable and asymptomatic cases may be treated conservatively. Early judicious use of osteotomy and acceptance of further surgical risks should be considered when there are significant symptoms and loss of function secondary to malunion. Nonunion, though rare, occurs more frequently in open fractures.

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See also Finger Sprain; Handlebar Palsy; Musculoskeletal Tests, Hand and Wrist; Trigger Finger; Ulnar Neuropathy

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Finger Sprain

Ligament injuries of the finger—commonly referred to as *sprains*—are frequently sustained during sports participation, largely due to the hand's role in absorbing the initial contact with players, playing equipment, and playing surfaces. Although many injuries are minor in nature, the potential for misdiagnosis of finger injuries as "jammed" or "sprained" remains high. Proper diagnosis and treatment of finger injuries require a fundamental understanding of the complex anatomy of the finger and its associated tendons and ligaments. Because a comprehensive discussion is beyond the scope of this entry, we will focus on the most common ligament injuries of the hand—those involving the proximal interphalangeal joints and the metacarpophalangeal joints.

Anatomy

The joints of the hand include the carpometacarpal joints, the metacarpophalangeal (MCP) joints, and the interphalangeal (IP) joints. Each finger has two IP joints: a proximal interphalangeal (PIP) joint and a distal interphalangeal (DIP) joint. The thumb has one IP joint.

The collateral ligaments of the MCP joints provide significant sideways (or lateral) movement when the fingers are extended. However, when the fingers are flexed, the collateral ligaments become tight, restricting lateral movement in this position.

The IP joints are strong, hinge-type joints and allow only flexion and extension. Ligaments create a three-sided box around each of these joints. Both MCP and IP joints have thick volar plates on the palmar surface, and the radial- and ulnar-positioned collateral ligaments provide stability while allowing up to 100° of flexion and some joint hyperextension.

PIP Joint Injuries

"Jammed" Finger

The PIP joint is most commonly involved. While most athletes report such injuries from catching or deflecting a ball or catching their finger in a jersey or face mask, this injury can occur in any sport involving a moving ball or player. Axial (downward) loading with hyperextension or valgus (inward) or varus (outward) stress on the joint provides the mechanism of injury in most cases. The radial collateral ligament is the most frequently injured, usually from its proximal attachment. Partial ligament tears predominate.

Volar (palm side) plate injuries usually involve hyperextension mechanisms. Rupture of the volar plate at its distal insertion is most common and manifests as point tenderness over the volar aspect of the base of the middle phalanx (finger bone). Volar plate injuries are often associated with collateral ligament injuries.

Injured athletes typically describe pain and swelling rather than instability. Evaluation should include inspection, palpation, and active flexion and extension of the PIP joint in isolation, which may reveal some instability. Additionally, valgus and varus stress should be applied with the PIP joint in 30° of flexion and the MCP joint in 90° of flexion. Laxity of the injured finger should be compared with that of an unaffected finger. If stress testing results in >20° of deviation, the collateral ligament is completely ruptured.

X-rays (anteroposterior, lateral, and oblique views) of the injured finger will assist in differentiating a sprain from a fracture or dislocation. Treatment depends on the ligament involved. For partial tears of the collateral ligaments, buddy taping (i.e., taping the injured finger above and below the joint) or splinting in full extension is recommended. If the ring finger is injured, it should be taped to the little finger to reduce the likelihood of injury to the little finger, which is naturally extended in the hand's rest position. The duration of treatment is dictated by pain during physical activity, but treatment is typically continued for 2 to 4 weeks.

For volar plate injuries without associated fracture, a progressive extension block splint should be used, starting at 30° of flexion for 1 to 2 weeks. PIP motion should begin following this initial period of immobilization, but significant extension or hyperextension should be avoided as these positions could compromise healing. A total of 4 to 6 weeks of extension block splinting should be completed, increasing the extension weekly to permit increased range of motion. Less severe volar plate injuries can alternatively be buddy taped.

Dislocated Finger

The PIP joint is also susceptible to dislocation resulting from a hyperextension injury. Dorsal dislocation is the most common, although lateral or rotary dislocations also occur. Rupture of the volar plate distally and the associated avulsion fracture commonly accompany this injury.

Reduction is accomplished by using steady traction on the distal phalanx, with slight hyperextension while applying direct pressure over the distal base. This allows the base of the middle phalanx to be gently manipulated over the articular condyles of the proximal phalanx. Once reduced, the PIP joint is continued through flexion. Neurovascular status should be assessed before and after the reduction attempts.

Dorsal and lateral dislocations without associated fractures should be managed in a dorsal splint in 30° of flexion for 3 to 5 days, followed by range-of-motion exercises with buddy taping for 3 to 4 weeks during sports participation. Preventing hyperextension, which may compromise healing of the volar plate, is a key treatment principle.

Thumb MCP Joint Injuries

Gamekeeper's or Skier's Thumb

Ligament injuries to the thumb most commonly involve the ulnar collateral ligament (UCL). Traditionally referred to as "gamekeeper's" or "skier's" thumb (the former being a reference to Scottish gamekeepers who forcefully applied pressure to the back of small animals' heads, thereby breaking their necks, as a means of instantly killing them), this injury typically results from forceful abduction and extension of the thumb, as occurs when a skier falls while holding a ski pole.

The UCL is usually disrupted near its insertion on the proximal phalanx. This injury may involve an isolated ligament tear, an avulsion fracture, or a combination of the two. Occasionally, the UCL becomes trapped outside the adductor aponeurosis, resulting in a Stener lesion. Stener lesions present with a mass over the ulnar side of the MCP and lack an end point when ulnar stress of the MCP joint is performed in both extension and 30° of flexion. Up to one third of UCL injuries involve Stener lesions.

Examination yields pain, swelling, and/or bruising over the ulnar aspect of the MCP joint. X-rays may show a small avulsion fracture involving the ulnar side of the first MCP base. Stress radiographs, performed with the MCP joint maximally flexed and with radially directed stress, are helpful in assessing stability. Greater than 35° of laxity implies instability.

Thumb spica splint immobilization for 6 weeks is the initial treatment for stable UCL injuries without fracture or with nondisplaced fracture. Surgery is the treatment of choice for Stener lesions or displaced avulsion fractures.

Athletes may return to play protected in a splint if comfortable and if their sport allows for thumb immobilization. Otherwise, return to play is allowable only when the joint is stable and healing has occurred.

Finger MCP Joint Injuries

The MCP joint of the finger is relatively resistant to ligamentous injury. When injury occurs, hyperextension is the typical mechanism, and partial ligament tears occur.

Dislocation of the MCP joint can accompany hyperextension injuries to the ligaments; most commonly, the index finger is involved, followed by the little finger. Dislocations are almost exclusively dorsal, resulting from volar plate rupture.

X-rays should be obtained to differentiate between a ligament sprain, dislocation, and fracture. Stress X-rays can be helpful in assessing for joint instability but should not be obtained in the case of nondisplaced avulsion fractures.

Partial MCP collateral ligament tears with or without minimally displaced or nondisplaced avulsion fractures are often treated with splinting for 3 weeks and with protective splinting during sports participation for an additional 3 weeks. The MCP joint should be splinted in 30° of flexion to prevent extension contracture. For the middle finger, buddy taping to an adjacent finger is an alternative to splinting. For the other fingers, buddy taping may be used after an initial course of splinting. Strengthening exercises should begin 6 weeks after injury.

If symptoms continue beyond 1 month despite conservative management or if instability develops, surgical treatment should be sought.

Peter Kriz

See also Finger Dislocation; Finger Fractures: Bennett Fracture, Boxer's Fracture; Finger Fractures: Overview; Thumb Sprain

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Fitness Testing

The importance of exercise in maintaining good health is becoming increasingly evident. This is highlighted by the American College of Sports Medicine's recent "Exercise is Medicine" campaign. It is recommended, however, that before beginning an exercise program, one should undergo an evaluation by one's primary physician, so as to determine if there are any contraindications or risks to exercise, to delineate any disabilities that require treatment and/or activity adjustments, and to elucidate one's current fitness level and specific exercise needs. Such fitness testing can also be used to monitor an individual's progress within an exercise program as well as to motivate that individual within his or her program. This entry discusses the importance and components of fitness testing.

What Is the Purpose of Fitness Testing?

One of the primary focuses of fitness testing is to highlight individuals at risk for exercise-related sudden death. This risk stratification involves several general categories, including the individual's age, medical conditions, coronary artery disease risk factors, and signs and/or symptoms of cardiovascular or pulmonary disease. Older age, greater than 45 years in men and greater than 55 years in women, is associated with increased risk. Women younger than 55 years, who have undergone menopause without hormone replacement therapy, are also at increased risk. Having an existing diagnosis of a cardiovascular, pulmonary, or metabolic disease can also increase one's risk of exercise-related sudden death. Pertinent cardiovascular diseases include heart disease, peripheral vascular disease, and coronary artery disease. Cystic fibrosis, chronic obstructive pulmonary disease (COPD), and asthma are among the pulmonary diseases associated with exercise-related sudden death. Common metabolic disorders associated with exercise-related sudden death include diabetes mellitus and thyroid disease.

Coronary artery disease risk factors are many. One coronary artery disease risk factor includes hypertension, either having a blood pressure >140/90 millimeters of mercury (mmHg) or taking an antihypertensive medication. Hypercholesterolemia, also a coronary artery disease risk factor, can consist of low-density lipoprotein (LDL) levels >130, high-density lipoprotein (HDL) levels <40, total cholesterol >200, or taking a lipid-lowering medication. An elevated HDL level (>60) is considered a negative risk factor. Another coronary artery disease risk factor is obesity, which can be defined as a body mass index (BMI) >30, a waist-to-hip ratio >0.95 in men and >0.86 in women, and a waist circumference >102 centimeters (cm) in men and >88 cm in women. A fasting blood glucose level of 100 or greater is a coronary artery disease risk factor, as is having a family history that includes acute myocardial infarction (MI) and sudden death in men <55 years old and in women <65 years old. The last two coronary artery disease risk factors are purely related to behavior—a sedentary lifestyle and smoking—currently or within the past 6 months.

Cardiovascular and pulmonary disease can also present with a variety of signs and symptoms. Cardiac symptoms include palpitations, heart murmur, chest pain, and other signs of myocardial infarction, such as jaw or arm pain. Shortness of breath with activity or at rest and unexplained fatigue can be symptoms of cardiac or pulmonary disease. Dizziness can be a symptom of cardiovascular insufficiency (i.e., inadequate blood flow), as can claudication (pain in the legs, associated with walking) and ankle edema (swelling in the ankles, related to poor blood return to the heart). Orthopnea, immediate difficulty breathing while lying flat, and paroxysmal nocturnal dyspnea, delayed difficulty breathing after lying flat, both relieved by sitting up, are also symptoms of cardiovascular disease, as the inadequate blood flow from the heart can cause fluid congestion in the lungs.

Components of Fitness Testing

Having an understanding of the purpose of fitness testing provides a foundation for the application of the components of fitness testing. There are five major parts of a fitness test, including (1) general health measurements, (2) body composition measurements, (3) cardiovascular assessments, (4) flexibility testing, and (5) muscular strength testing (i.e., the force generated by muscle or muscle group) and muscle endurance testing (i.e., the ability of a muscle or muscle group to contract repeatedly over a period of time). The most commonly used general health measurements include height, weight, resting heart rate, and resting blood pressure. The body composition measurements most commonly performed include skin fold testing, approximating total body fat based on caliper measurements at the abdomen, ilium, triceps, and thigh; BMI, the ratio of one's weight (in kilograms) to the square of one's height (in meters); waist circumference; waist-to-hip ratio; and bioelectrical impedance analysis. Less commonly used body composition measures include hydrostatic weighing for body fat and bone density testing (via dual-energy X-ray absorptiometry [DEXA] or total body electrical conductivity [TOBEC]).

Cardiovascular components of fitness testing are many and may vary in their use based on the individual's fitness level and capabilities, as well as on the exact purpose of the test. If feasible, the individual may be tested with field tests outside, such as a 12-minute run, a 1.5-mile (mi; 2.41-kilometer [km]) run, or a 1-minute walk. If outside testing is unavailable or unfeasible, step testing can be performed. Treadmill testing is another viable indoor option and includes tests such as the 1-mi (1.61-km) walk and the Bruce and Balke-Ware protocols, which gradually increase the metabolic equivalents (METs, representing the physiologic intensity level of exercise) that apply to the individual. The Bruce protocol, with its relatively rapid and large rise in METs per stage, is most commonly used for young and athletic individuals. The Balke-Ware protocol, with its smaller escalation in METs per stage, is more suited to older and less fit individuals.

The last two components of fitness testing include flexibility and muscle strength and endurance testing. The most common flexibility test is the sit-and-reach test, which measures how far one can reach beyond one's toes from a seated-forward bend. Additional flexibility testing involves measuring individual joint angles. Muscle testing involves testing both the strength of muscles, with heavy resistance and fewer repetitions, and the endurance of muscles, with light resistance and more repetitions. Commonly used muscle tests include the grip test, the dynamometer, chin-ups, push-ups, sit-ups, curl-ups, and the bench press.

Should an individual be at moderate or high risk of exercise-related sudden death (see Table 1), he or she may benefit from graded cardiovascular exercise testing with a monitored physiologic response. The individual would participate in indoor treadmill testing, using either the Bruce or the Balke-Ware protocol mentioned earlier, for example, while the evaluator monitors the individual's heart rate and blood pressure response, electrocardiogram (EKG),

Table 1 Risk Level of Exercise-Related Sudden Death

Risk Level	*Age (years)*	*Symptoms*	/	*Risk Factors*
Low	Men: <45 Women: <55	None	or	≤1
Moderate	Men: >45 Women: >55	None	or	≥2
High	Men: >45 Women: >55	≥1	or	cardiac, pulmonary, or metabolic disease

rate of perceived exertion (RPE), METs, and/or $\dot{V}O_2max$. A monitored exercise test may be stopped if the individual requests that the test be stopped, the clinician monitoring the test requests that the test be stopped, the individual develops symptoms of physiologic stress, the maximum limit for the test has been reached, or the ACSM (American College of Sports Medicine) conditions for stopping have been met.

Who Performs Fitness Testing and Under What Conditions?

After understanding how fitness testing is performed, it is important to understand who performs fitness testing and under what conditions it should be performed. Fitness testing should be performed in a safe environment of low stress to the individual. This includes providing sufficient patient education as to the various components of the test as well as providing a quiet and comfortable environment with a relaxed, confident, and competent staff. Generally considered safe, exercise testing can be performed by exercise physiologists, physical therapists, nurses, physician's assistants, and medical technologists. As the rates of cardiovascular complications during exercise testing in the presence of paramedical personnel and in the presence of physicians are similar, it is considered appropriate to have paramedical personnel present during the test or to have the test conducted under the direct supervision of a physician in the immediate vicinity. A physician must directly supervise an exercise test if the patient has recently undergone a cardiac event or if the patient requires graded exercise testing. Supervising physicians must have knowledge and understanding of the following: basic exercise physiology, cardiovascular and hemodynamic responses to exercise, and the effects of aging disease, and medication on exercise; the indications for, contraindications to, methods of, appropriate and necessary modifications to, and reasons for termination of exercise testing; and the American Heart Association–approved cardiopulmonary resuscitation and advanced cardiac life support training.

Conclusion

Fitness testing, involving general health and body composition measurements, cardiovascular and flexibility assessments, and muscular strength and endurance testing, can be used as a tool to determine an individual's physiologic readiness to participate in exercise. The results of an individual's fitness test can be used to create an exercise prescription, as well as to monitor that individual's fitness level in the future.

Nailah Coleman

See also Aerobic Endurance; Cardiac Injuries (Commotio Cordis, Myocardial Contusion); Chest and Chest Wall Injuries; Exercise and Heart Murmurs; Exercise Physiology; Exercise Prescription; Hypertension (High Blood Pressure); Physiological Effects of Exercise on Cardiopulmonary System; Preparticipation Cardiovascular Screening; Pulmonary and Cardiac Infections in Athletes; Respiratory Conditions; Sudden Cardiac Death; Target Heart Rate

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Flat Feet (Pes Planus)

Pes planus (flat feet), sometimes referred to as "fallen arches," is a condition where the long arch of the foot collapses or never develops. It is a condition that can have a serious effect on an athlete's performance, as well as predispose the athlete to injury.

At birth, infants usually appear to have no arch due to the amount of fat they have in this area as well as the loose ligaments that are common in infancy. The arch will develop in most children by the time they are 2 to 3 years old. In adults, pes planus can develop over time from mechanical stress that occurs as the result of anatomical problems, prolonged stress on the foot, the aging process, diseases such as diabetes, or faulty biomechanics.

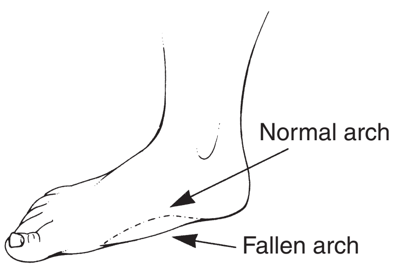
There are generally two types of flat feet, rigid and flexible. Another way to look at the condition is to see whether the foot is structurally flat or whether it flattens out. People can also develop flat feet over time.

It is important to diagnose what factors contribute to the individual's condition so that treatment is appropriate.

The Rigid Flat Foot

A rigid flat foot can be associated with a fusion of two or more bones in the foot, called a coalition. A coalition will limit motion in the foot, often leading to pain and deformity. This condition can be usually diagnosed with X-rays or computed tomography (CT). The condition will stop motion at the site of the joined bones. Depending on the bones joined, symptoms can vary from localized pain to painful muscle spasms that greatly limit activity. Treatment can consist of orthotics and physical therapy, but sometimes surgery is needed if conservative care fails to give the patient relief.

A rigid flat foot can also result from the progressive collapse of the arch over time with associated arthritis. The causes of this collapse can vary among structural variants in the foot, bad biomechanics that put stress on the feet, diabetes, injury, and improper footwear.



Flexible Flat Feet

A child or adult with a flexible flat foot will usually have a normal-looking arch when he or she is not bearing weight, such as when on an examining table. However, when the individual stands, the arch will collapse, sometimes causing the bones of the foot to contact the ground. Usually, the individual can stand on his or her toes and re-create the arch. These individuals will lack the "rigid-lever" effect of the foot at toe-off. This can lead to poor performance, improper biomechanics, and injury in both the foot and the legs. Some examples of injuries that can occur are shin splints, stress fractures in the feet and legs, and patellofemoral syndrome.

Conditions That Can Lead to Flat Feet

Some structural variants that can lead to flat foot are an accessory navicular, an extra bone that can get in the way of the supporting structures of the foot; a bony blockage in the front of the ankle that over time leads to mechanical stress on the bones of the foot, leading to collapse of the arch; and even a high arch. In individuals with a high arch, osteoarthritis can develop in the midfoot area, leading to damage to the bones and support structure, which can eventually lead to collapse of the arch.

Biomechanics and the Development of Flat Feet

Poor biomechanics can result in forces that cause the foot to flatten when the individual stands or flat foot to develop slowly over time. This can arise from conditions such as leg length inequality, genu varum (bowlegs), lack of or excessive tibial torsion (the "twist" of the lower leg from the knee to the ankle), genu valgum (knocked knee), or tight calf muscles. By identifying the cause of the deforming force, treatment can be properly focused on the cause rather than the result. This can also help the athlete identify a biomechanical problem that may be interfering in performance in other areas—for example, a figure skater who cannot get an inside edge and who is bowlegged.

Treatment

Some doctors advocate no treatment unless symptoms arise. However, if deforming forces are present that are affecting the athlete's performance or have the potential of causing irreversible damage later in life, early treatment is warranted. If an injury is present, it is important to determine the role of the foot's mechanics in the athlete's problem.

Again, treatment should be directed at the causative factor(s). Something as simple as a heel lift in an individual with an anterior ankle block or a lift in an athlete with leg length inequality can be all that is needed. In cases with injuries resulting from the flat or flattening foot, a team approach may be more appropriate. For example, a treatment regiment here could run the spectrum from orthotics to control the foot mechanics to surgery on a knee to repair a torn meniscus.

The athletic coach should be made aware of any findings; these could help contribute to the athlete's performance and overall well-being.

Thomas Vorderer

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Foot and Ankle Injuries, Surgery for

The ankle and foot play a major role in virtually all types of athletic competition. Any sport that requires running, jumping, or rapid change of direction places significant demands and high-energy stress on the bones, tendons, and ligaments of the foot and ankle. Sports such as football, basketball, baseball, soccer, and track-and-field events are just a few examples of high-impact activities that commonly result in foot and ankle injury. A clear diagnosis is imperative to initiate appropriate treatment and optimize rehabilitation. In some cases, surgery is indicated as the primary mode of treatment, but in most cases, initial management most often consists of the RICE mnemonic: *r*est, *i*ce, *c*ompression, and *e*levation. Surgery is often required for fractures, repeated injury, or joint instability or if initial attempts at conservative treatment fail.

Ankle and Foot Anatomy

The *ankle joint* and the *subtalar joint* complex (subtalar, talonavicular, and calcanoecuboid joints) are the key to hindfoot function. The ankle joint is a *mortise and tenon* joint connecting the lower leg and the foot. It is formed by the *talus* (ankle bone), which fits into a socket formed by the lower ends of the *tibia* (shinbone) and the *fibula* (a thin bone on the outside of the leg). The tibia and fibula form a sturdy unit (or mortise) that cups the talus (or tenon). The ends of the tibia and fibula have bony prominences called *malleoli,* which help hold the talus in the correct position during movement. The surfaces of the talus, tibia, and fibula that articulate (rub) during ankle motion are covered by smooth cartilage (e.g., gristle on a chicken bone) to minimize friction. Below the ankle joint is the subtalar joint, which is formed by the bottom of the talus and the top of the *calcaneus* (heel bone).The talus is mostly cartilage surface contributing to the ankle joint, the subtalar joint, and the talonavicular joint. The three joints of the subtalar complex, the talonavicular, subtalar, and calcanoecuboid, all work together, and if there is abnormality in one of them, it will affect overall subtalar movement and function.

The rest of the foot is very complex, as there are 28 bones and more than 30 joints in the foot. The *tarsal* bones of the foot connect to the talus and calcaneus at the back and the *metatarsals,* the five long bones of the foot, in front. Each of the five metatarsal bones connects to one of the five toes (the first metatarsal connects to the big toe).

The muscles of the ankle and foot can be divided into *intrinsic* and *extrinsic* muscles. Intrinsic muscles (within the foot) serve mainly to move the toes and support the arch of the foot. Extrinsic (outside) muscles arise on the lower part of the leg. Each of the extrinsic muscles has a tendon that crosses the ankle joint. Tendons are strong fibrous bands of tissue that connect muscles to bone and provide the force needed for movement. Tendons arising from the extrinsic muscles of the lower leg assist in movement of the ankle, foot, and toes. Ligaments are strong fibrous bands of tissue that connect bone to bone for stability. Three important sets of ligaments hold the bones of the ankle in correct alignment, providing further stability.

Ankle Joint Function

The mortise and tenon nature of the ankle joint mainly allows the foot to move upward (*dorsiflexion*) and downward (*plantarflexion*) during running and walking while providing a great degree of stability to the joint. The side-to-side motion generally attributed to the "ankle" actually comes from the subtalar joint, which is not as constrained.

The strength and power needed for movement at the ankle comes from four groups, or *compartments,* of muscles in the lower leg. Two compartments are behind (posterior to) the tibia. The calf muscles are in the more *superficial* (surface) posterior compartment and are connected by the Achilles tendon to the heel bone. This connection provides the strength used to push off the ground when running or jumping. Under the calf muscles is the *deep* posterior compartment of muscles, which allows for rotation of the foot inward toward the body (inversion). There is one muscle compartment in the front (anterior) of the leg that provides force for upward movement of the foot. Overuse of the muscles in the *anterior* or deep posterior compartment can be a cause of "shin splints" (discussed in a separate entry). There is one muscle compartment outside (*lateral*) the leg that mainly provides force for rotation of the foot outward, away from the body (eversion).

Foot and Ankle Injuries

Both the professional athlete and the "weekend warrior" place enormous amounts of strain on the ligaments, tendons, and bones of the foot and ankle during competition. When the demands of an activity are too great, the result can be tearing, inflammation, or fracture of these structures. For the majority of sports-related foot and ankle injuries, initial attempts at treatment are conservative. Treatment consisting of rest and immobilization, ice, anti-inflammatory medications, and a course of physical therapy is usually quite successful. In severe injuries, or when these methods fail to produce satisfactory results, surgery may be necessary to help the athlete get back to competition. Decreased stability as assessed by the surgeon on physical exam and confirmed by X-rays of the ankle joint is the most important factor guiding the need for surgery. Ligament *sprains,* chronic *tendinitis,* tendon *rupture,* and *fractures* often result in instability or dysfunction and often require surgery. It is important to understand that all surgeries carry the risk of infection, bleeding, pain, and possible damage to the surrounding nerves or vessels. Additionally, after any operation involving the foot and ankle, a course of immobilization is usually required during the initial period of healing. This can involve a cast or a splint and may require the athlete to be non–weight bearing on the affected leg for a period of time. A course of physical therapy to achieve normal muscle strength and range of motion is also essential to the success of any operation and will help facilitate a much quicker return to competition.

Sprains

Sprains are the most commonly encountered sports-related foot or ankle injury, especially in sports that require quick changes of direction. About 25,000 people experience an ankle sprain each day. Sprains arise when the ligaments connecting two bones together are stretched more than normal. The classic example is when an athlete "rolls" an ankle. There are three degrees of ligament sprain. Grade I sprains are the most common, and in this case, the ligaments are often not actually torn but have been stretched to the point where they are microscopically damaged. There is no instability, and these mild sprains require less treatment and time to heal. A Grade II sprain is more severe, with the ligaments having been partially torn. A Grade III sprain indicates that the ligament has been significantly damaged or completely torn to the point where there is instability of the joint. With all degrees of sprain, there is associated swelling, pain, and bruising.

Acute (sudden) sprains are treated conservatively and usually heal well on their own with proper rest and rehabilitation. Multiple acute sprains or the failure of the ligaments to heal properly can lead to *chronic instability*. With severe sprains, there may be an associated fracture of any of the bones that make up the ankle joint, most commonly one of the malleoli. With chronic instability, damage can result in abnormal motion of the joint and loss of stability. This level of injury often requires surgery to repair ligaments or fix broken bones in position to allow for proper healing and stability.

Surgery for Ankle Fractures

Severe sprains are often associated with fractures, commonly malleolar fractures. Because it is the function of the malleoli to hold the ankle joint in place, malleolar fracture can result in instability. A lateral (outside) malleolar fracture is a fracture of the end of the fibula. Surgery is not always required, but if the bone is out of place or the ankle is unstable, the bone pieces can be “fixed” together with either a plate and screws on the side of the bone or a rod on the inside of the bone to keep the fragments in place as they heal. A medial (inside) malleolar fracture is a fracture of the shinbone. Similar techniques are used in surgery to treat medial fractures. Sometimes medial fractures are treated with surgery even if the ankle is not unstable to decrease the risk of *nonunion* (not healing). Postoperatively, immobilization is usually required until healing occurs, and then, motion and strengthening exercises are initiated. Weight bearing is also increased as healing progresses and is confirmed with X-rays; healing usually takes approximately 4 to 6 weeks.

Surgery for Severe Sprains and Instability

The *lateral* (outside) *ligaments* are the most commonly sprained. This occurs during an injury in which the foot “rolls” inward (inversion), putting stress on the outside of the ankle. Surgery for an acute sprain is rare but mainly involves *arthroscopy,* during which small cameras are placed inside the joint to visualize and remove loose fragments of bone or cartilage. Multiple sprains can lead to *lateral ligament instability,* a chronic condition in which the ankle tends to roll into inversion during routine activity because the ligaments no longer provide enough support on the outside of the ankle.

There are two categories of surgery for lateral instability. *Anatomic repair* is preferred because it is a smaller surgery and maintains normal motion of the joint. It involves direct repair and tightening of the torn lateral ligaments with sutures. In cases where the ligaments are too badly damaged for anatomic repair, the ligament is replaced with a piece of one of the healthy tendons from the patient’s ankle. In this procedure, holes are drilled into the fibula and talus to anchor the tendon to its new location. This procedure, *tenodesis* or tendon transfer, provides a great deal of stability at the cost of decreased ankle and subtalar motion and a bigger incision. After surgery, 3 to 6 weeks of cast immobilization, followed by a course of strengthening and rehabilitation, is required.

The *syndesmotic ligaments* connect the tibia and the fibula together to form the upper part of the ankle joint. Syndesmotic sprains are commonly referred to as “high ankle” sprains and tend to take longer to heal than the more common lateral sprains. Syndesmotic sprains are most often treated with a non–weight-bearing cast for 6 weeks. If a bone fracture at the ankle is also seen, syndesmotic sprains are frequently unstable. For unstable sprains, surgery may be necessary for placement of a screw(s) to hold the tibia and fibula together while the ligaments heal.

The *deltoid ligament complex* on the inside of the ankle is injured when the foot is rolled toward the outside of the body, putting stress on the inside of the ankle. These sprains are seldom seen without a simultaneous fracture or syndesmotic sprain. Surgery is only required when deltoid sprains are associated with ankle fracture or syndesmotic sprains, leading to instability, but it consists of the same techniques discussed previously.

Another injury seen in athletes is the *Lisfranc sprain,* occurring at one or more of the joints connecting the small *tarsal* bones in the middle of the foot and the longer *metatarsal* bones in the front of the foot. A simple ligament sprain at the Lisfranc joint will cause dislocation of the small bones of the foot. A more severe Lisfranc sprain may be associated with fracture of the metatarsals. Surgery consists of percutaneous (through small puncture holes in the skin) placement of screws or wires across the Lisfranc ligament to fix the bones in the correct anatomic position. With severe displacement of the site of injury, an incision or multiple incisions may be required to put the injured bones back in place and stabilize with screws. After surgery, patients are non–weight bearing for at least 6 weeks, and screws are kept in place for 6 to 12 weeks.

Tendon Problems

Tendon problems of the foot and ankle are common in athletes. Tendinitis represents overuse injury that causes the muscle tendon to become irritated and inflamed. This inflammation, if not properly treated with rest and anti-inflammatory medications, can lead to degeneration of the tendon, which then predisposes to rupture or tearing of the tendon. Rupture can be either partial or complete and is an important cause of pain and instability of the joint that may require surgery. Management of tendon problems is initially conservative, with rest, ice, anti-inflammatory medications, and physical therapy. Tendinitis and even tendon ruptures are often able to heal on their own without surgery. The most commonly injured tendon in the ankle is the Achilles tendon, which connects the calf muscles to the heel bone. Normal function is essential for jumping, running, and other sporting activities. Partial and complete Achilles tears can be treated nonoperatively with immobilization; however, it is reasonable to suggest operative treatment when the patient is active and healthy in order to hasten recovery and return to sport.

Surgery for Tendinitis and Tendon Rupture

Surgery for tendon problems is used to treat inflammation and tendon damage before degeneration occurs and to repair partially or completely torn tendons. Inflammation of the sheath surrounding a tendon, or of the tendon itself, can be treated with debridement (removal of damaged tissue), done through incisions or alternatively through small holes with cameras, called *tendoscopy.*

Surgery for an Achilles rupture involves *approximating* the two ends of the torn tendon close together with sutures to allow healing. This is the best option for acute tears when there are sufficient healthy tendons available. Reconstruction of the tendon with a graft (healthy tendon harvested from another part of the body) is a better choice for more chronic cases with a long history of tendinitis because the tendon is not as healthy and is more likely to rerupture. Surgery to repair other ruptured tendons in the ankle is less common but can also involve using graft or tendon transfer. Rehabilitation in these cases often involves walking in a walking boot with a heel lift for the first few weeks to reduce tension on the repair site. The heel lift can be reduced every 2 weeks and discontinued 6 weeks after surgery. At 6 weeks, strengthening and gradual return toward activity can begin.

Stress Fractures

Stress fractures of the smaller bones of the foot are seen in athletes, most commonly in the fifth metatarsal (outside the foot) and the navicular bone. With repetitive activity, overload of these bones can occur, and the repetitive stresses can cause a stress fracture or crack in the bone. Most stress fractures can heal with rest and protective braces or inserts for 2 to 4 weeks. Stress fractures may require surgery to ensure adequate immobilization and to promote timely healing.

Surgery for Stress Fractures

Surgery for stress fractures is often important to ensure that the injury heals properly. In athletes, surgery is also a consideration because it may speed return to sport. Surgery for navicular fractures involves placing a screw across the fracture line to fix pieces firmly together. For fifth metacarpal fractures, a screw is placed inside the bone (intramedullary) to allow for healing. Postoperatively, weight bearing and return to activity depend on healing of the fracture as seen clinically, on X-rays, and on special scans such as magnetic resonance imaging (MRI) or computed tomography (CT).

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See also Foot Fracture; Foot Injuries; Foot Stress Fracture; Morton Neuroma; Plantar Fasciitis and Heel Spurs; Tendinitis, Tendinosis

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Foot Fracture

Foot fractures require special attention in the world of sport. Whether it is the basketball player cutting to the basket, the ballet dancer en pointe, or the snowboarder losing the edge, the foot is vulnerable to fracture in many different ways. The human foot is placed under an extraordinary amount of stress during sports. Injury to the foot can mean pain and loss of productivity for the weekend warrior or the end of a career for the elite athlete. Injuries to the foot are common. Acute fractures occur less frequently than stress fractures but are important to recognize as diagnosis can sometimes be difficult. This entry first outlines general principles and then goes on to discuss specific fractures.

General Principles in Fracture Management

The human foot is essential for mobilization, and as such, delay in the diagnosis and treatment of fractures can result in long-term consequences such as chronic pain, immobility, stiffness, loss of balance or position sense (proprioception), decreased range of motion, and loss of strength.

To diagnose a fracture, a thorough history and physical exam are essential. Knowing exactly how the injury occurred provides clues to diagnosis. During a physical exam, point tenderness is the best indicator of injury. It is crucial to understand the anatomy. Physicians consider the Ottawa Ankle/Foot Rules when deciding to X-ray the foot (see the entry Ankle Injuries). X-rays should be obtained if there is

- bone pain in the foot,
- tenderness at the base of the fifth metatarsal bone, or
- tenderness over the navicular bone or
- if the patient cannot take four steps bearing weight on the foot.

Suggested views are anterior-posterior, oblique, and lateral, to best visualize the complex architecture in the foot. Once the fracture is identified, it should be reduced (realigned) as quickly as possible to minimize the swelling that comes with the injury. Sometimes surgery may be required to achieve the best alignment.

It is important, while dealing with a fracture in the foot, to recognize the important role of therapy and rehabilitation early in an effort to prevent long-term complications. Immobilization should be limited to as short a time as possible, though sometimes it is essential to proper healing. Work to restore motion early, and when immobilizing the foot or ankle, allow motion in the toes to prevent stiffness and future complications in rehabilitation.

Proximal Fifth Metatarsal Fracture

The proximal fifth metatarsal is vulnerable to fracture in sports. The location of the fracture depends on the mechanism of the injury. You can recognize the base of this bone as the "bump" along the outside (lateral) portion of the foot. There are essentially two types of acute fracture.

The most proximal (closest to the heel) is an avulsion fracture. This occurs with an extreme inversion of the ankle (the sole of the foot folds inward). Avulsion literally means that the muscle tendon that attaches at this location (peroneus brevis) tears off the end portion of the bone. This causes a fracture, usually diagonally, through the base of the metatarsal. The fracture is usually easy to see on an X-ray. So long as the fractured portion is not severely displaced, it can heal well by treating the foot one would treat a severe lateral ankle sprain. Immobilization can help reduce the pain but is not necessary for healing. With initial weight bearing as tolerated in a hard-soled shoe, this fracture can heal in as few as 6 weeks. If it is significantly displaced, it may require surgery with a screw or pin to hold it in place while it heals.

The next fracture to the proximal fifth metatarsal happens slightly more distal than the avulsion (further toward the toe) and occurs by a different mechanism. The Jones fracture occurs with medial to lateral force, similar to the cutting maneuver common in soccer or basketball. The pressure placed on the proximal fifth metatarsal (outside the planted foot) is so severe that a fracture occurs. This fracture is notoriously more difficult to heal and is seen as a more horizontal fracture on X-ray, generally. Its healing process involves non–weight-bearing immobilization for 6 to 8 weeks and then slow reintroduction of weight while in a postoperative shoe for several more weeks. In high-performing athletes, this extended time off is often detrimental, and so surgical screw fixation hastens return to sport. In this case, non–weight bearing 1 week after surgery, then 2 to 3 weeks in a postop shoe is suggested. Full return to the sport can occur within 6 to 10 weeks.

Lisfranc Fracture/Dislocation

The tarsometatarsal joint is the junction between the metatarsal and the tarsal bones. It can be approximated by finding the highest point of the arch on the dorsal (top) surface of the foot just before the foot slopes down to the toes. This joint constitutes the junction between the midfoot and the forefoot.

Fractures can occur anywhere along the joint lines. Common injury mechanisms in sports come from extreme force being applied to the heel of a planted forefoot. This is most common in contact sports and in ballet, if the dancer's weight shifts too far forward, buckling the joint. With this fracture, the ligaments holding the bones in place are often damaged, causing a dislocation or separation of the bones. Hence, the resulting injury, often called a Lisfranc fracture (after Napoleon's surgeon, who first noticed the pattern of the fracture), is termed a *fracture dislocation.*

Diagnosis is often difficult but important, because if missed and left untreated, Lisfranc injury can cause chronic foot pain and disability. Most often, swelling is seen on top of the foot and bruising at the bottom. There is pain while pressing along the joint line and with passive movement. Stressing the joint with weight-bearing X-rays will reveal the dislocation if present.

Treatment is based on the stability of the joint and the severity of the fracture. A stable joint responds to the conservative treatment of initial non–weight bearing in a molded cast with progression to full weight bearing. Repeat X-rays are done to ensure proper alignment while in the cast. For an unstable joint or severe fracture, surgery may be necessary. The goal of surgery is to obtain proper anatomic alignment, often with the use of wire or screws to secure the bones. Postoperative care is similar to postoperative care for proximal fifth metatarsal fracture in that it involves non–weight bearing for an initial amount of time followed by progressive weight bearing. If treated appropriately, this injury can heal well after proper rehabilitation.

Lateral Process of the Talus Fracture

The talus, located above the calcaneus (heel bone), is involved in rotation and hinging movements and creates the ankle joint with the distal tibia and fibula. The lateral process can be felt as the bony prominence just inferior to (below) the lateral malleolus. Fracture to this lateral process is seen almost exclusively in snowboarding, earning it the name "snowboarder's fracture." During a fall while tethered to a snowboard, the ankle is inverted with extreme dorsiflexion (flexed up) and external rotation, leading to a fracture and pain directly at the site of this process. The pain is very similar to a severe lateral ankle sprain, but a fracture should be considered in snowboarders. If left undiagnosed, it can lead to chronic pain, arthritis, and long-term disability in an otherwise healthy young athlete. When this injury is suspected, it is often difficult to confirm. A special "mortise"-view X-ray or a computed tomography (CT) scan is best. Fractures that are minimally displaced can respond to 4 to 6 weeks' non–weight bearing with a short leg cast, followed by another 4 to 6 weeks in a walking boot with protected weight bearing. If the fracture is more severely displaced, it may require surgical fixation or removal of the fracture fragments. It is important to start rehabilitation soon after cast removal to prevent the common complication of chronic pain.

Toe Fractures

Toe fractures may be the most common foot fractures in sports. These fractures are usually from crush or stubbing injuries. Pain is focused at the fracture site. These fractures can usually be managed with "buddy taping" to the adjacent toe until the pain resolves. If the fracture is open (breaks through the skin), if blood flow is impaired, or if the fracture involves a joint, it should be seen by a surgeon. If the first (big) toe is fractured, the patient should also wear a hard-soled shoe during the healing process because this helps redistribute the weight and reduce the stress on the toe. Surgery is uncommon but is necessary for severe fractures.

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See also Ankle Injuries; Foot Injuries; Foot Stress Fracture

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Foot Injuries

Foot injuries are fairly common in sports and can present as both acute and chronic problems. They are particularly common in running, jumping, and kicking sports such as football, basketball, and soccer, as well as in dance and gymnastics. Acute injuries include fractures, ligament and tendon injuries, and more minor injuries such as blisters and contusions. Chronic or overuse injuries include stress fractures and tendon injuries.

Anatomy

The foot can be divided into three distinct regions: (1) the rear foot or hindfoot, consisting of the calcaneus and talus; (2) the midfoot, consisting of the three cuneiform bones, the navicular medially, and the cuboid laterally; and (3) the forefoot, consisting of the five metatarsals and corresponding phalanges. The calcaneus is the biggest and strongest bone in the foot and serves as the attachment for the Achilles tendon as well as the origin of the plantar fascia. The calcaneus and talus form three articulations. The subtalar or talocalcaneal joint allows inversion and eversion of the foot. The navicular serves as the attachment for the posterior tibialis tendon. The great toe has a proximal and distal phalanx, whereas the other four toes have proximal, middle, and distal phalanges. On the plantar aspect of the first metatarsal-phalangeal joint (MTP), there are two pea-sized bones called sesamoids in the substance of the flexor hallicus brevis tendons. The sesamoids help increase the mechanical advantage of the flexor tendons and disperse forces with gait and stance.

In children, there are areas of new bone growth called apophyses. In the foot, there is an apophysis in the calcaneus and at the base of the fifth metatarsal. The apophyses are attachment points for tendons. The Achilles tendon attaches to the calcaneal apophysis; the peroneal tendon attaches to the base of the fifth metatarsal. Traction of the tendons can cause inflammation of the apophyses, resulting in traction apophysitis. The base of the fifth metatarsal is also subject to avulsion fractures in children.

Two important ligaments in the foot are the spring ligament and the Lisfranc ligament. The spring or calcaneonavicular ligament prevents talar head sag and medial migration of the talus, thereby stabilizing the medial arch of the foot. The Lisfranc joint divides the foot into the midfoot and forefoot and comprises the five MTP joints. The Lisfranc or tarsometatarsal (TMT) ligament is the main stabilizer of the Lisfranc complex. It originates on the lateral aspect of the medial cuneiform and inserts on the medial aspect of the second metatarsal base dorsally and plantarly.

The muscular anatomy of the foot comprises three compartments: (1) the anterior, (2) the lateral, and (3) the posterior. The boundaries of these compartments are formed by the interosseous membrane and anterior crest of the tibia. The anterior compartment is made up of the extensor hallucis longus, extensor digitorum longus, and anterior tibialis and primarily dorsiflexes the ankle. The anterior tibialis attaches to the first cuneiform and metatarsal and inverts the foot. The peroneus longus and brevis constitute the lateral compartment and evert the foot. The peroneal brevis attaches to the base of the fifth metatarsal; the longus crosses the sole of the foot and attaches to the first cuneiform and base of the first metatarsal. The posterior muscle compartment has superficial and deep groups. The superficial group is the triceps surae, comprising the gastrocnemius, soleus, and plantaris. The deep group includes the flexor hallucis longus, flexor digitorum longus, and tibialis posterior muscles, which function to flex the ankle and toes and invert the foot. There are many intrinsic muscles in the foot. The plantar fascia runs from the inferior aspect of the calcaneus to the forefoot and helps support the arch of the foot.

The sciatic nerve provides primary innervation of the foot. The dorsiflexors of the foot and ankle are innervated by the common peroneal nerve. The tibial nerve innervates the intrinsic muscles of the foot, except for the extensor digitorum brevis. The peroneal muscles are innervated by the deep peroneal nerve.

Evaluation of Injuries

Details of Injury

As with any injury, the mechanism can help determine the nature of the injury. Injuries may be acute, resulting from a fall or twist, or chronic, where pain develops over time. In acute injuries, the athlete may be unable to bear weight after the injury. There may be swelling or bruising at the site of injury. The athlete may have heard or felt a "pop" or "snap" at the time of injury. There may have been previous injuries to the same or opposite foot.

With chronic or overuse injuries, there may be mechanical symptoms, such as snapping, clicking, or locking. Intermittent swelling is also possible with chronic injuries. The athlete may also have weakness or decreased balance. Activities that aggravate the athlete's pain may help point to possible causes. Details of treatment to date, including medications, investigations, braces/orthoses, and physiotherapy, can help guide further management.

Other details that can help in management of a foot injury include athlete-specific questions, such as what sport(s) they play, what level of competition, what position, where they are in their season, and any changes in training (intensity, duration, frequency). "Red-flag" symptoms, such as fevers, weight loss, chills, night sweats, rashes, or localized warmth and redness, as well as a family history of juvenile idiopathic arthritis, tarsal coalition, multijoint laxity, or other chronic health problems can indicate other causes of foot pain, such as infection or arthritis.

Physical Findings

Athletes may be predisposed to foot injuries because of their body type and stage of development. Heavier athletes may have more chronic foot pain. Athletes with poor lower extremity alignment, such as flat feet or bowlegs, may have foot pain. An athlete with a foot injury may walk differently or be unable to bear weight at all. The gait may be antalgic (shortened stance phase), flat footed (no movement at the ankle), or "deweighted" (walking on the foot in an area that is not painful, for instance, walking on the heel if the toe is sore).

There may be an obvious deformity, swelling, redness, or bruising of the foot. Range of motion of the injured foot may be decreased compared with the noninjured side. Subtalar motion can be assessed by observing the heel move to varus with toe raise and the ability to walk on the lateral border of the foot; it can also be assessed by "rocking" the mid- and forefoot in and out.

Palpation of the foot can determine the area of maximal tenderness. Tenderness along the bones may indicate a fracture or stress injury. Tenderness along the Achilles tendon may indicate tendinitis. Tenderness along the ligaments indicates a sprain. Sesamoiditis usually causes tenderness to palpation of the sesamoid bones.

Injuries to the foot may result in neurological abnormalities, such as decreases in the tone, strength, sensation, and deep tendon reflexes. There may be impairment of the blood supply to the foot, as well as abrasions, lacerations, redness of the skin, or rashes.

Table 1 Foot Injuries

Foot Region	*Common*	*Less Common*
Rear foot	Plantar fasciitis	Calcaneal fractures
	Fat pad contusion	Calcaneal stress fracture
	Sever disease (calcaneal apophysitis)	Talar stress fracture
		Retrocalcaneal bursitis
		Osteochondritis dissecans of the talus
		Reflex sympathetic dystrophy (RSD)
Midfoot	Navicular stress fracture	Stress fractures
	Tibialis posterior tendinopathy	Peroneal tendinopathy
	Extensor tendinopathy	Cuboid syndrome
		Tarsal coalition
		Kohler disease
		Accessory navicular bone
		Lisfranc joint injury
		RSD
Forefoot	Corns, calluses	Freiberg osteochondritis
	Hammertoe	Islen disease
	First metatarsophalangeal joint sprain (MTP) joint sprain (turf toe)	Sesamoid stress fracture
	Subungal hematoma	Stress fracture of base of second metatarsal
	Morton neuroma	RSD
	Sesamoiditis	
	Stress fracture of metatarsal	
	Metatarsal fractures	
	Fracture of fifth metatarsal	
	Toe fractures	
	Hallux valgus (bunion)	

Investigations

X-rays are helpful to look for acute fractures, healing stress fractures, or the presence of bony abnormalities, such as tarsal coalition, bone spurs, or bony tumors. Weight-bearing X-rays should be ordered to maintain the foot in its usual functional position. Stress fractures usually require isotopic bone scan for diagnosis, followed by computed tomography (CT) or magnetic resonance imaging (MRI). Ultrasound can be helpful for soft tissue injuries such as tendinopathies, plantar fasciitis, or Morton neuroma.

Types of Injury

For a list of sports-related foot injuries, see Table 1.

Prevention of Injury

One of the key ways to prevent foot injuries is to ensure overall fitness level and good conditioning. Maintaining an appropriate weight with proper nutrition and healthy lifestyle behaviors is essential for overall good health.

Prior to the start of an athlete's season, a preparticipation exam can help identify any injuries or

Perform exercises as instructed below, stopping with any sharp pain.

1. Toe raises, both legs together: 1–3 sets of 15 repetitions
2. Toe raises, injured leg alone: 1–3 sets of 15 repetitions
3. Balance on the injured leg: 1–3 sets, 30 seconds in duration
4. Walk at fast pace: 1–3 times, 50 yards each
5. Jumping on both legs: 1–3 sets of 10 repetitions
6. Jumping on injured leg: 1–3 sets of 10 repetitions
7. Easy pace straight line jog: 1–3 times, 50 yards each
8. Sprint (half speed, quarter speed, and full speed): 1–3 times each, 50 yards each
9. Jog straight and gradual curves: 2–3 laps around field, court, or track

Cross-country, track, and running can gradually advance to desired distance at this point. More demanding sports (football, soccer, basketball, baseball, tennis) need to advance to more sport-specific drills, such as the following:

1. Running figure-8s (half speed, quarter speed, and full speed): 1–3 times each
2. Crossovers, 40 yards: 1–3 times to the right and left each
3. Backward running (backpeddling): 1–3 times, 40 yards each
4. Cutting (half speed, quarter speed, and full speed): 1–3 times
5. Sport-specific drills
6. Return to sport

Figure 1 Functional Return-to-Sports Protocol

muscle imbalances that may predispose the athlete to injury during the season and allow for targeted efforts to correct imbalances and rehabilitate injuries in the preseason. Athletes should wear the proper protective equipment for their sport and ensure that the equipment is appropriately maintained and replaced as necessary. Taping or supportive bracing should be employed for athletes who are injured. At the start of practice sessions and games, participants should "walk the field" to identify any potential hazards, including debris on the playing surface or uneven playing surfaces. In practice sessions, emphasis should be laid on appropriate warm-ups and skill drills to improve strength, flexibility, and neuromuscular control. Such drills could include jumping, landing, cutting, and balance training.

Return to Sports

Return to sports after an injury is somewhat injury specific. In general, however, the athlete should be able to walk, run, hop, jump, and do everything necessary for his or her sport without pain. Depending on the injury, the athlete may have to be non–weight bearing for a period of time to allow healing to occur. During this time, the athlete can participate in non–weight-bearing aerobic activity, such as swimming and stationary biking, to maintain cardiovascular conditioning and increase blood flow to the extremity. Physical therapy can help improve swelling, range of motion, strength, and balance.

When pain has resolved and the athlete is able to fully bear weight, he or she can then proceed through a functional return-to-sport protocol (Figure 1). This protocol should be supervised by an athletic trainer, physiotherapist, or physician. As long as the athlete does not experience any sharp pain with activity, he or she can progress to more advanced tasks. To prevent reinjury once the athlete returns to sport, athletic taping or a foot orthosis may be necessary for the remainder of the sport season. The athlete may be able to return to a less demanding player position sooner than to his or her typical position.

Laura Purcell

See also Arch Pain; Cyst, Ganglion; Foot Fracture; Foot Stress Fracture; Hammertoe; Morton Neuroma; Overpronating Foot; Plantar Fasciitis and Heel Spurs; Retrocalcaneal Bursitis; Sesamoiditis; Sever Disease

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Foot Stress Fracture

A *stress fracture* can occur when a particular bone is subjected to repeated stresses (such as stretching or compressing forces). Stress fractures are most commonly seen among athletes and military recruits. The reported incidence of stress fractures is less than 1% in the general population, but it may be as high as 20% in runners.

The pathophysiology of a stress fracture has been well described in the literature. The repetitive stresses on normal bone result in microfractures that need to remodel, but the bone is unable to keep pace with the remodeling of the microfractures, and thus, multiple microfractures consolidate into a larger stress fracture.

There are multiple factors that may increase the risk of a stress fracture. The more common intrinsic risk factors include low bone mineral density (weaker bones), pathologic bone states (abnormal starting bone), hormonal imbalances (which influence the ability to remodel), and muscle fatigue (which increases the load on the bone). Extrinsic risk factors associated with stress fractures include excessive volume or intensity of training over time, change in the training surface, training shoes that have lost cushioning, inadequate nutrition, and cigarette smoking.

Stress fractures are classified into low risk and high risk by their risk of complications, such as nonunion, and are commonly distinguished by the fracture site. Low-risk sites are generally amenable to nonoperative management, compared with high-risk stress fractures, which are often managed with internal fixation.

Weight-bearing bones are at greater risk for stress fracture. In one study, tibial stress fractures accounted for 49.1% of all stress fractures seen in athletes, followed in frequency by tarsal (25.3%), metatarsal (8.8%), and sesamoid (0.9%).

Low-risk stress fractures of the foot include fractures of the second through fourth metatarsal shafts and the calcaneus. The sites at high risk of complications include the medial malleolus, the talus, the navicular, the proximal fifth metatarsal, the base of the second metatarsal bone, and the great toe sesamoids.

History

Obtaining a complete and detailed history is essential when suspecting a stress fracture. Initially, the foot pain is mild, and it occurs at the end of a training session. Cessation of the aggravating activity may alleviate the pain. If ignored, the pain usually worsens and will start to occur during activity and eventually constantly.

Assessing for the presence of intrinsic and extrinsic risk factors is important. In female athletes, the menstrual history should be obtained. A training history and previous history of lower extremity injuries are helpful in the diagnosis.

Metatarsal Stress Fractures

Metatarsal stress fractures had been termed *march fractures* since they were commonly found in military recruits. In athletes, the incidence of metatarsal stress fractures is second only to the incidence of tibial stress fractures. Of all metatarsal stress fractures, 90% occur in the second, third, and fourth metatarsals. Several weeks after an abrupt increase in activity or with chronic overload and pes planus, the risk of metatarsal stress fracture is increased.

There are multiple factors that increase weight-bearing loads or decrease the ability to handle loads on a particular metatarsal, predisposing individuals to metatarsal stress fractures. Anatomic abnormalities such as dorsal- or plantarflexed metatarsals, a long second metatarsal, or excessively tight gastrocnemius muscles are factors that have been associated with metatarsal stress fractures. Other associated factors include obesity or osteopenia associated with amenorrhea and external factors such as poorly fitting shoes.

A disproportionate number of stress fractures occur in the second metatarsal shaft, especially at the neck. This is possibly due to its increased rigidity, being more firmly fixed at the tarsal-metatarsal joint.

History and Physical Examination

The proposed mechanism of injury is a repetitive stress to the forefoot, usually from running, jumping, dancing, and other repetitive weight-bearing activities. Patients with a metatarsal stress fracture commonly describe a history of gradually worsening pain in the forefoot that is initially intermittent and occurs only with use. Patients may present with poorly defined forefoot pain or point tenderness over a metatarsal shaft.

Examination will reveal pain at the fracture site with gentle axial loading of the metatarsal head. This maneuver should not produce pain in patients with only soft tissue injury. Weight bearing is often possible but usually produces pain.

Imaging

Anteroposterior (AP)/lateral radiographic films are important as the initial imaging study and may reveal evidence of a stress fracture. In patients, evidence of stress fracture can usually be seen no earlier than 2 to 6 weeks after the onset of symptoms. Distinct, well-organized callus is usually seen after several months. Bone scan or magnetic resonance imaging (MRI) is very helpful when X-rays are negative and there is clinical suspicion of stress fracture. Some recent reports of diagnostic ultrasound to diagnose stress fracture are promising.

Treatment

Considered a low-risk stress fracture, most metatarsal shaft stress fractures do not require casting or immobilization. Nonoperative management consists of cessation of the causative activity for 4 to 8 weeks. Crutches and partial weight bearing for several weeks should be used in patients who have pain with walking. A short leg cast and non–weight bearing can be used for short periods of time in patients with severe pain. Higher-impact activities can be resumed gradually after 4 to 8 weeks if there is no pain with normal activities.

Nonsteroidal anti-inflammatory drugs (NSAIDs), theoretically, may impair bone healing. It would be prudent to avoid or limit usage during recovery, especially if pain is hindering return to play.

Sesamoid Stress Fractures

The two sesamoid bones beneath the first metatarsophalangeal (MTP) joint sustain 12% of injuries to the great toe complex. These sesamoids are embedded within the tendon of the flexor hallucis brevis, and they provide a mechanical advantage for the MTP joint. The medial sesamoid bears greater force during the normal gait cycle and is more commonly fractured from either direct force or cumulative stress.

History and Physical Examination

The proposed mechanism of injury in sesamoid stress fractures is described as sports that require rapid acceleration and deceleration, such as tennis, racquetball, football, soccer, and volleyball. Patients with a sesamoid stress fracture usually complain of poorly localized pain around the first MTP joint for several weeks. Swelling is not generally seen until the injury has progressed, and erythema is typically absent.

Examination consists of direct palpation over the injured sesamoid that is causing pain. The tender spot will move with flexion and extension of the first ray. Passive dorsiflexion of the first MTP can elicit pain in sesamoid fractures. Holding the MTP in maximal dorsiflexion and deeply palpating the suspected area while the patient tries to plantarflex the great toe is another useful test.

Imaging

Standard radiographs (AP, oblique, and lateral views) of the foot are generally sufficient to demonstrate sesamoid fractures (these may not show initially). Special views such as lateral oblique (which shows the fibular sesamoid), medial oblique (which shows the tibial sesamoid), and sesamoid can be obtained if standard X-rays are negative and there remains a high index of suspicion.

Like scaphoid fractures, sesamoid fractures may not be apparent on initial radiographs. X-rays should be repeated after 2 weeks of presumptive therapy. If a fracture is strongly suspected but initial films are negative or when the diagnosis is unclear (such as a partite sesamoid), a bone scan or MRI can be helpful.

Treatment

The majority of these fractures can be managed nonsurgically. Treatment is controversial. Abstaining from the activity thought to have caused the fracture is common to all approaches. In addition, some type of padding or bracing footwear is used, including C- or O-shaped padding around the sesamoid to unload it, molded orthosis, wooden-soled shoes, or short leg walking boots. Padding, use of a firm-soled shoe, or immobilization should be continued for 6 to 8 weeks. Initial follow-up is done 1 to 2 weeks after diagnosis and monthly thereafter.

Open or displaced sesamoid fractures, which are rare, should be treated operatively. If healing of nondisplaced fractures has not occurred by 4 to 6 months (nonunion) or if symptoms are still bothersome after 4 to 6 months, sesamoidectomy may be necessary. After the initial 6- to 8-week treatment period, patients may return to activities as their symptoms permit.

Navicular Stress Fractures

Navicular stress fractures can be difficult to diagnose and treat because of their often vague clinical presentation and the poor correlation between radiographic and clinical presentations. Although these fractures were previously thought to be less common, more recent studies have reported their incidence to be as high as 35% of all stress fractures.

Both the kinematics of the navicular joint and its blood supply contribute to the characteristic location of stress fractures in this bone. During heel strike, the navicular is compressed between the talus and cuneiforms, and this places force on the central third of the bone. This part of the navicular also has decreased vascularity compared with the medial and lateral portions, thus making it more vulnerable to stress fractures.

History and Physical Examination

A high index of suspicion for navicular stress fracture is necessary in the approach to treating an active patient who complains of foot pain. In other words, if a weight-bearing athlete experiences an insidious onset of midfoot pain, a stress fracture of the navicular must be ruled out, even if radiographs are normal. Patients often complain of pain with an insidious onset that worsens during and following physical activity. Sprinting, jumping, and pushing off are movements that particularly aggravate the condition. A vague pain along the longitudinal arch on the dorsomedial aspect of the foot may be the initial complaint, but as the condition progresses, the pain is often localized to the dorsum of the navicular bone. Patients also may report a recent increase in the intensity or duration of physical activity or a change in equipment or technique.

Physical examination should include palpation of the foot to identify areas of tenderness and swelling. Navicular stress fractures typically are tender over the "N" spot, which is defined as the proximal dorsal portion of the navicular. Symptoms may also be reproduced by hopping on the affected leg with the foot in an equinus position.

Imaging

Conventional radiographs of the weight-bearing foot should be obtained for patients in whom navicular stress fractures are suspected. The fracture is usually in the middle third of the bone and oriented in the sagittal plane. However, radiographic results may be normal in the acute phase and may not demonstrate changes until 3 to 6 weeks after the injury.

If the initial radiographic evidence is normal, additional studies may include computed tomography (CT), MRI, or bone scan. Bone scan is a sensitive modality for evaluating a possible navicular stress fracture. A negative result reliably rules out a stress fracture; however, a positive result is nonspecific and requires clinical correlation and further imaging.

Treatment

These are high-risk fractures; aggressive nonoperative treatment can be considered for fractures involving less than 50% of the navicular. Nonoperative treatment should begin with a non–weight-bearing cast for a period of at least 6 weeks, by which time the fracture would have healed. If tenderness has resolved after the period of casting, then weight bearing can resume, and functional rehabilitation can be started. If pain persists, then the patient can be allowed to bear weight in a boot until the pain resolves. Patients may require up to 8 months before return to full activity. Operative treatment consists of percutaneous screw fixation. Generally, bone grafting is reserved for chronic fractures and delayed union or nonunion.

Fifth Metatarsal Stress Fractures

Background

A fifth metatarsal fracture is considered a high-risk fracture. Fractures of the fifth metatarsal are separated into three zones. Zone 1 is the most proximal and includes the metatarso-cuboid articulation, the insertion of the peroneus brevis, and the lateral plantar aponeurosis. Zone 2 fractures start at the metaphyseal-diaphyseal junction and are usually transverse in nature. Zone 3 fractures include the proximal 1.5 centimeters of the diaphysis. Zone 1 fractures are usually the result of an acute indirect injury and are typically avulsion-type fractures. Zone 2 fractures are usually the result of a large adduction force to the forefoot with plantarflexion. Zone 3 fractures usually are associated with repeated stress beneath the fifth metatarsal head.

Stress fractures of the fifth metatarsal are usually Zone 3 fractures and occur less frequently than the acute types. The prognosis and treatment differ substantially among the zones. The most difficult distinction to be made is between acute fractures and stress fractures of the proximal diaphysis. Despite their infrequency, they deserve special attention because of their marked propensity for delayed union and nonunion as compared with other proximal fifth metatarsal fractures and stress fractures of other metatarsals.

History and Physical Examination

Patients usually experience a prodrome of pain up to several months prior to presentation that is characteristically more intense during exercise or other weight-bearing activity. Tenderness is present over the fracture site. Occasionally, edema and/or ecchymosis may be present over the site.

Physical examination should include inspection, palpation for the point of maximal tenderness, and neurovascular assessment. The clinician should briefly evaluate adjacent structures, including the other metatarsals, the tarsals, and the ankle.

Imaging

Standard X-rays of the foot (AP, oblique, and lateral) should be obtained. Stress fractures are most commonly seen just distal to the intermetatarsal articulation (between the bases of the fourth and fifth metatarsals). However, stress fractures may also occur more proximally, where they can be confused with an acute fracture. Radiographic findings vary depending on the stage of the stress fracture.

MRI or bone scan should be considered for patients in whom clinical suspicion remains high but follow-up X-rays at 2 weeks fail to reveal any evidence of fracture.

Treatment

Stress fractures of the proximal diaphysis of the fifth metatarsal have high rates of nonunion. A classification system for predicting outcome and planning treatment has been developed. In contrast to acute fractures, where the fracture line is sharp and the surrounding bone appears normal, the bone surrounding stress fractures appears abnormal. An early stress fracture will demonstrate cortical thickening (Torg Type I). An older stress fracture will demonstrate a widened fracture line and partial (Torg Type II) or complete (Torg Type III) obliteration of the medullary canal. Misclassification can lead to inappropriate treatment, potentially causing delayed healing.

The ideal candidate for nonoperative management is a patient with a Type I fracture who can tolerate prolonged non–weight-bearing immobilization in a short leg cast for 6 to 12 weeks, even up to 20 weeks if necessary. Rest, ice, compression, and elevation with acetaminophen help reduce symptoms. As with other stress fractures, the use of NSAIDs is best avoided. Nonunion may still occur, and early operative fixation is a viable option, especially for athletes or extremely active patients. In athletes, early surgical fixation is generally preferred to minimize deconditioning and enable a quicker return to competition. While Torg Type II fracture may occasionally be a candidate for nonoperative management, surgical fixation should be considered in Torg Type II and all Torg Type III fractures. Bone stimulators may help decrease healing time, but a definitive reduction in healing time has not been reported.

Surgery consists of intramedullary screw fixation. Portland and colleagues recommend surgical fixation for Torg Type I fracture, since it might facilitate quicker fracture union rates and return to activity. It is suggested that following intramedullary screw fixation, the aftercare involves non–weight bearing for 2 weeks, then placement in a cam walker boot as tolerated. Radiographs should be repeated every 2 weeks until full union is achieved. Patients may return to full activities within 6 to 8 weeks.

For both nonoperative and operative care of the fracture, once healing is clearly present, as evidenced by callus formation and/or resolution of tenderness, the cast may be discontinued, and the patient may begin gradual, progressive weight-bearing and range-of-motion exercises. Physical therapy is helpful when immobilization exceeds 2 to 3 months. Cross-training with cycling and swimming can help the patient regain cardiovascular fitness while minimizing the impact on the foot. High-impact and high-stress activities, such as jumping and pivoting, should be reserved for the final stages of rehabilitation.

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See also Foot Fracture; Foot Injuries; Running Injuries

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Football, Injuries in

The game of football is one of the most popular sports in the United States, with an estimated 1.5 million participants yearly. A variety of medical and musculoskeletal issues need to be considered at all competitive levels. In fact, it was safety concerns about the early game of football, and its notorious "flying wedge" formation, that led to the establishment of the National Collegiate Athletic Association (NCAA) at the urging of President Theodore Roosevelt, when colleges banded together with the goal of reforming football to limit the injuries (and fatalities). Football is the leading cause of sports-related injuries, with an injury rate almost twice that of basketball, the second most popular sport. Between 300,000 and 1.2 million high school athletes are estimated to sustain football-related injuries annually.

Common Injuries in Football

Sprains and strains account for approximately 40% of injuries, with contusions 25%, fractures 10%, dislocations 5%, and concussions 5%. More than 50% of injuries occur in the lower extremity, while upper extremity injuries account for approximately 30%. The most frequently injured are the knee (medial collateral ligament [MCL], followed by meniscus and anterior cruciate ligament [ACL]), ankle, shoulder, and upper leg. Patterns of football injuries vary by type of exposure and level of play. A recent NCAA study demonstrated that injury rates are greater in games than in practice, football injury rates in spring are greater than in the regular season, and preseason rate of injury is higher than both regular-season and postseason rates. Running plays were the leading cause of injury, with running backs and linebackers being the positions most commonly injured. Approximately 50% of players at all levels will be injured to some extent during each season.

Cardiopulmonary disease (including arrhythmias, hypertrophic cardiomyopathy, and myocarditis) and asthma account for most of the nontraumatic deaths in football players. Heat illness and blood dyscrasia, such as sickle cell hemoglobinopathies, are important entities to identify as they are often precipitators of nontraumatic deaths.

When the Player Has "the Wind Knocked Out"

A blow to the abdomen may cause a sudden contraction of the abdominal muscles, forcing the diaphragm upward. This results in a reflex contraction of the intercostal and serrati muscles to stabilize the rib cage and causes a forceful expiration that is maintained for a few seconds due to the muscle spasm. The athlete becomes acutely aware of the inability to breathe until muscle relaxation occurs, which allows for spontaneous recoil of the displaced structures and inspiration.

Concussion Management

Concussion is the most common head injury in football. Approximately 250,000 such concussions occur yearly. Common symptoms are dizziness, headache, visual disturbance, and nausea, often with confusion, disorientation, or an altered level of consciousness. Accumulative damage can occur from repeated concussions, resulting in the increasing severity and duration of each subsequent concussion, and catastrophic brain hemorrhage and swelling can occur rarely (second-impact syndrome) if return to play is allowed while still symptomatic. Long-term complications in athletes who have suffered multiple concussions show a greater decline in cognitive dysfunction than in the general population.

Sports medicine staff should be trained in the recognition and management of concussion. Many classification systems exist in the literature, but there is no universal agreement regarding the grading systems, and they should only act as a guide for sideline management. If the athlete has had his or her "bell rung," serial examinations should be performed every 15 minutes. Athletes who have symptoms for only a brief period of time can return to competition if symptoms completely resolve and they are appropriately stress exercised on the sideline before returning to competition. Athletes exhibiting amnesia, those who have sustained a documented loss of consciousness, and those with persistent symptoms should not be allowed to return to participation on the day of injury. Return to play should not be permitted unless the athlete has completely recovered from the concussion. Postconcussive symptoms such as persistent headache, irritability, fatigue, visual difficulties, dizziness, behavioral problems, school difficulties, and/or inability to concentrate may persist, and athletes should be banned from competition until the problems resolve. Return to competition guidelines for multiple concussions are even more subjective. The length of time before return to contact sports depends on the number of concussions as well as the timing and severity of each episode. In the 2004 Prague consensus guidelines, concussions are graded as either simple or complex, depending on the symptoms, timeline, and level of consciousness. Each athlete needs to be individually counseled about return to play, and factors such as level of play, importance of play to the athlete, and potential health risks and consequences should be involved in the decision-making process. Neuropsychological testing and brain imaging may be used in the evaluation and monitoring.

Injuries Common in Football

"Burners" or Stingers

"Burners" or stingers are believed to be traction or compression injuries of the brachial plexus causing traumatic neuropraxia of the involved nerve roots (C5-C6). The athlete complains of unilateral burning/stinging, numbness, and tingling radiating into the upper extremity, frequently with weakness, in the absence of neck pain. The most common motor deficit is deltoid weakness, so shoulder abduction should be routinely checked in all athletes with burners. Symptoms usually resolve within minutes, and if there is no pain or motor weakness on examination, the athlete may return to competition. Athletes should be counseled regarding neck and upper extremity strengthening and range-of-motion (ROM) exercises, the proper tackling technique, and protective measures such as a neck roll and proper fitting equipment. Bilateral symptoms should be immobilized with appropriate workup for cervical spine injury or transient quadriplegia.

Turf Toe

The injury known as *turf toe* is a sprain of the plantar capsular-ligament complex, occurring most often from a hyperextension injury at the large toe metatarsal-phalangeal (MTP) joint as another player falls on the elevated heel. It often occurs in football linemen pushing off on the artificial turf, and examination demonstrates pain at the MTP joint beginning several hours after the initial injury, with ecchymosis, swelling, and plantar tenderness beneath the metatarsal head. X-rays are negative, and initial treatment includes *r*est, *i*ce, *c*ompression, and *e*levation (RICE), nonsteroidal anti-inflammatory drugs (NSAIDs), and anti-inflammatory physical therapy modalities. Doughnut padding and special taping techniques stabilize the joint during motion, with orthosis and properly fitted shoes with a rigid forefoot to facilitate return to play. Full participation can begin as soon as the player can tolerate full weight bearing.

"Hip Pointers"

"Hip pointers" result from either a contusion to the iliac crest or separation of muscle fibers pulled from the crest, resulting in marked local pain, swelling, and considerable disability in the athlete. Tenderness and lameness may persist for days or weeks following this injury. An X-ray may be taken to rule out iliac crest fracture, especially in the high school athlete who may avulse the iliac crest apophysis. Early treatment with compression dressings, ice, rest, and NSAIDs should be instituted. Contrast thermal modalities, ultrasound, and steroid injection may speed recovery. Return to play with protective hip padding is allowed when the pain is tolerated and gait has returned to normal.

Blocker's or Tackler's Exostosis

This is an area of painful bony prominence occurring as a result of direct blows to the anterolateral humerus distal to the edge of the shoulder pads. This bone forms in continuity with the cortex, grows by accretion, and results from periosteal damage at the insertion of the deltoid or at the brachialis origin. Early recognition and treatment are important as the localized pain and swelling can be disabling. Initial treatment consists of ice, rest, compression dressing, and hematoma aspiration if necessary. Local padding is usually sufficient to allow play, and surgical excision is required only if the area remains painful despite conservative management.

Jersey Finger

The injury commonly known as "jersey finger" is an avulsion of the flexor digitorum profundus. It is commonly seen in a player who attempts to tackle an opponent by grabbing his or her jersey. It presents as an inability to flex the distal interphalangeal (DIP) joints independently. Appropriate diagnosis and early surgical reattachment are the treatment of choice.

Thigh Contusions

Thigh contusions from direct blows are treated with pain relievers, ice, massage, and ultrasound to prevent progression to myositis ossificans.

Management of Cervical Spine Injuries

Axial loading of the spine is the suspected mechanism of cervical spine injury in football. When a player lowers the head to ram an opponent, the cervical spine is straightened, converting a normally lordotic cervical spine into a segmented column. At the time of collision, the head stops, but the trunk keeps moving, compressing the cervical spine. When the compressive force from an axial load cannot be dissipated by controlled motion in the spinal segments, a cervical spine injury may occur.

If cervical spine injury is suspected, helmet and shoulder pad removal on the field should be delayed until the injured athlete can be transported to a location where more definitive management can take place. If necessary, helmet and shoulder pads should be removed simultaneously. Athletic trainers and/or prehospital staff should be equipped with the knowledge and proper equipment to remove the face mask if airway access is required.

Equipment removal on the field should only be considered in the event of a cardiorespiratory emergency.

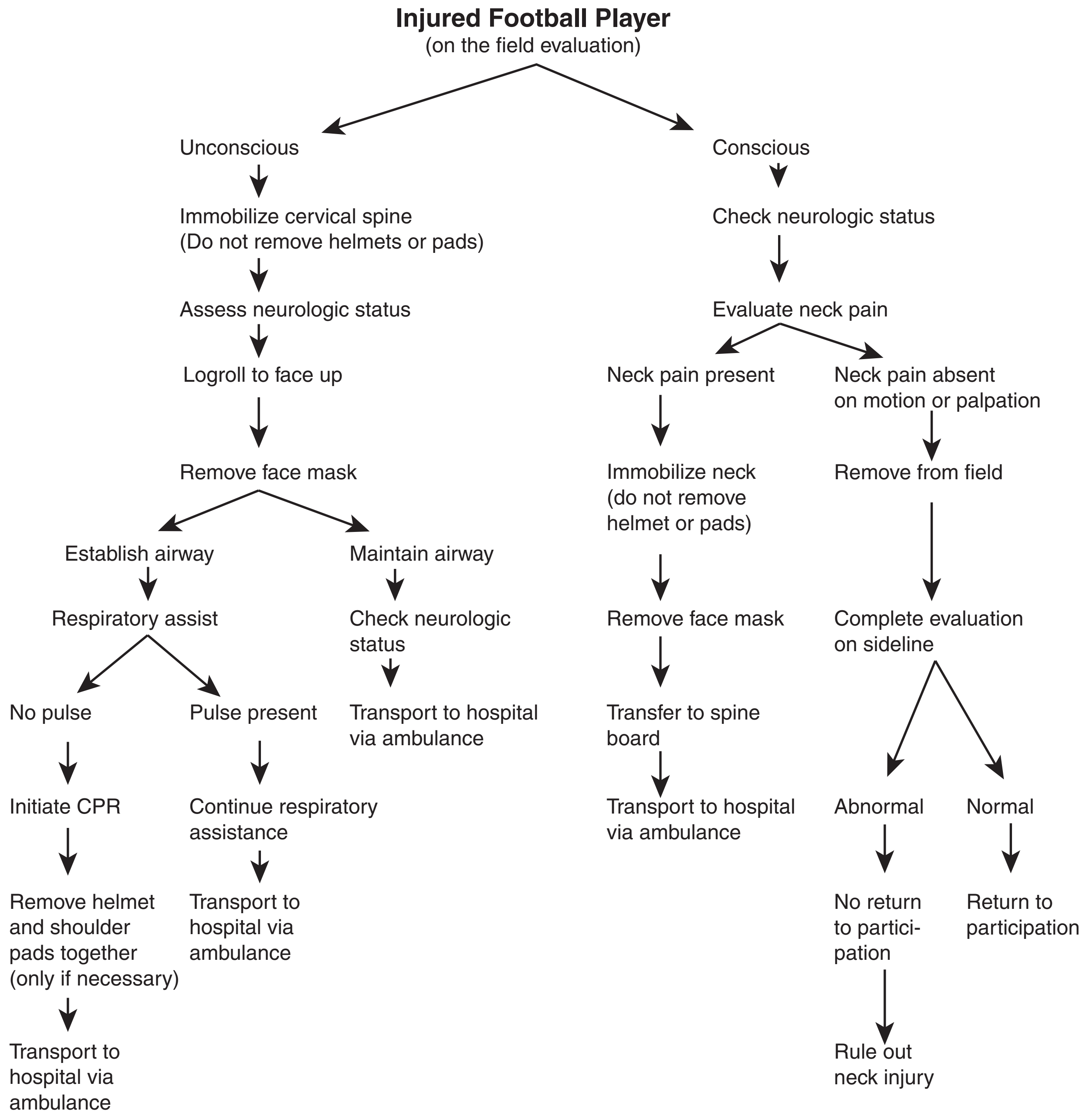

Figure 1 Algorithm for Field Decision Making in Head and Neck Injuries

Source: Waninger KN, Lombardo JA. Football. In: Mellion MB, Putukian M, Madden C, eds. *Sports Medicine Secrets*. 3rd ed. Philadelphia, PA: Hanley & Belfus; 2003:437–446.

An algorithm for an organized, systematic approach to the athlete with head and neck injuries is outlined in Figure 1.

Kevin N. Waninger and F. Dale Bautista

See also Anterior Cruciate Ligament Tear; Catastrophic Injuries; Head Injuries; Neck and Upper Back Injuries; Protective Equipment in Sports; Team Physician

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Forearm Fracture

The upper extremity is involved in approximately one half of all fractures seen in adults and children. Most upper extremity injuries, whether sports related or not, typically occur after direct trauma or a fall on an outstretched hand (FOOSH). Forearm fractures most commonly occur in children, accounting for 10% to 45% of all pediatric fractures. Treatment options vary depending on the patient's age, type of fracture, degree of displacement or instability, and level of sports participation. Younger patients have a greater potential for bone remodeling and better chances of obtaining good functional outcome without surgery. However, return-to-play decisions, particularly for contact sports, are difficult due to the potential for refracture during the weeks that follow the period of initial immobilization. Bracing and other protective devices may be used, but they often have a limited role for sports participation and may not fully protect against the risk of refracture or subsequent injury.

Anatomy and Clinical Evaluation

Normal range of motion (ROM): elbow flexion/extension 0° to 150°, wrist flexion 80°, and wrist extension 45°. With forearm rotation, the ulna lies in a relatively straight and fixed position, while the radius rotates about the ulna. The neutral position, or 0°, is when the palm faces medially and the thumb is directed up. *Normal ROM:* forearm pronation +90° and supination −90°. With forearm fractures, proper restoration of the normal anatomic alignment is essential for good functional outcomes.

Neurovascular structures run across the forearm and are at risk for injury. The radial nerve courses over the lateral epicondyle and radial head, traveling along the length of the radius. Radial nerve function is tested with thumb extension and sensation over the dorsal aspect of the thumb. The ulnar nerve sits within the ulnar groove between the medial epicondyle and olecranon, running through the forearm along the ulna. Ulnar nerve function is tested with finger abduction/adduction and sensation over the small finger of the hand. The median nerve travels over the anteriormedial aspect of the distal humerus and elbow joint and continues along the interosseous membrane. Decreased sensation at the tips of the index or middle finger and diminished pinch strength with the thumb and the index finger are an indication of median nerve injury.

Physical examination includes a careful inspection for deformities and characterizes areas of tenderness, particularly olecranon, if at the radial head, and physes (growth plates) if skeletally immature. An open fracture should be suspected if there are any lacerations. If there is an obvious deformity, ROM evaluation of the joints can be temporarily deferred. Every exam must include a thorough neurovascular evaluation distally before and after any manipulation or splinting. If there is a concern for a neurovascular deficit, an emergency referral should be made to an orthopedic surgeon. Although uncommon, swelling from injuries can increase forearm compartment pressures, resulting in an acute compartment syndrome.

Diagnostic Imaging

Plain radiographs (anteroposterior and lateral) of the forearm should be obtained for every suspected forearm fracture. It is essential to adequately image the elbow and wrist; therefore, frequently additional radiographs specific to the elbow and wrist are obtained in patients suspected of fracture. Comparison views are often obtained in skeletally immature patients as they can increase the likelihood of detecting subtle fractures or physeal injuries.

Radius Fractures

With a FOOSH injury, most of the axial loading force from the fall will be transferred to the distal radius rather than the ulna. Therefore, distal radius fractures are more common than midshaft or proximal radius fractures. Overlying muscles protect the radial shaft; therefore, injuries severe enough to cause radial shaft fractures will typically also involve ulna fractures or joint dislocations. Unlike distal radius fractures, it is uncommon to have an isolated radial shaft fracture; therefore, examiners should be suspicious for associated injuries. Nondisplaced fractures can be treated with splinting and then cast immobilization. Displaced fractures typically require a closed reduction followed by immobilization in a long arm cast or splint.

A *Galeazzi fracture* is a radius fracture, typically at the junction between the middle and distal third, with a distal radioulnar joint (DRUJ) dislocation. Signs and symptoms that suggest an injury to the DRUJ include widening of the DRUJ on radiographs, fracture of the ulnar styloid, or pain with stressing or "piano keying" of the DRUJ. A Galeazzi fracture should be splinted and immediately referred to an orthopedic surgeon for definitive treatment. A "reverse Galeazzi" fracture is a distal ulna fracture with a DRUJ dislocation. These fractures tend to heal poorly if treated nonoperatively.

Ulna Fractures

A "nightstick" or isolated ulna fracture is typically caused by a direct blow, such as when using the forearm to protect oneself from a blow to the head or trunk. This can occur in sports that use blocking techniques, such as martial arts, lacrosse, and football. The ulna acts as the main strut of the forearm; therefore, displaced, angulated, or comminuted fractures should be referred for orthopedic evaluation and possible surgical fixation. A long arm posterior splint at 90° of elbow flexion and neutral forearm and wrist position can be used initially until reevaluation within 7 to 10 days. Athletes with stable, well-aligned forearm fractures are often transitioned to a forearm plaster sleeve or functional brace for 4 to 6 weeks. A sleeve or brace will allow for elbow and wrist function without compromising ulna healing and may shorten the rehabilitation time needed to regain the strength and motion required for safe return to sports. Patients are seen frequently, with radiographs obtained weekly initially to ensure that alignment is maintained and to monitor healing through the appearance of bony callus. A failure to maintain adequate alignment, despite adequate immobilization, is always an indication for prompt surgical referral.

A *Monteggia fracture* is a fracture of the ulna with an associated radial head dislocation. A dedicated radiocapitellar view may identify subtle radial head injuries. On any radiograph of the radiocapitellar articulation, a line drawn down the center of the radial shaft through to the radial head should always bisect the capitellum. If this does not occur, one can suspect a radial head injury. With Monteggia fractures, an urgent referral to an orthopedist for surgical repair is necessary.

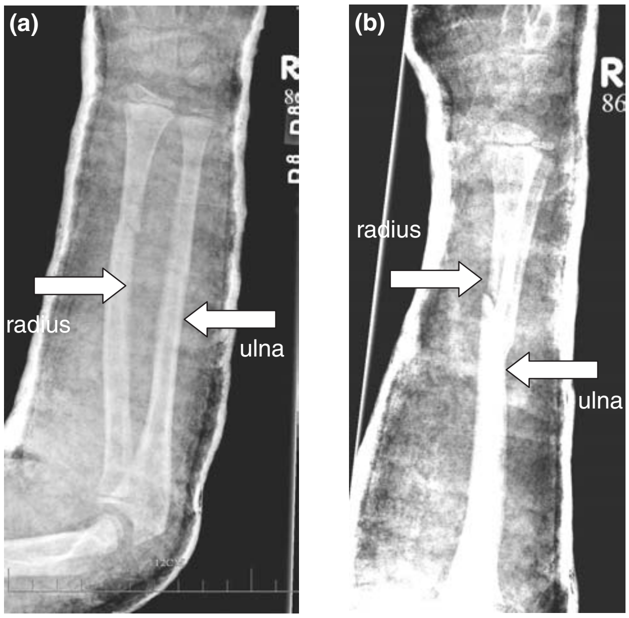
Both-Bone Forearm Fracture

Fractures involving both the radius and the ulna are FOOSH-type injuries, typically resulting from high-energy mechanisms such as tackling, takedowns, and collisions that occur during participation in contact sports. When both the radius and the ulna are injured, the fractures are inherently more unstable and there is a greater likelihood of extensive soft tissue injury. The presence of any neurovascular compromise is an indication for immediate fracture reduction in an emergency room or operative setting with adequate analgesia. Even after closed reduction, a majority of these fractures will still require surgical fixation to achieve better functional outcomes.

Displaced both-bone forearm fractures requiring a closed reduction and immobilization or an open reduction/internal fixation are more common than nondisplaced both-bone fractures. Stable fractures are frequently treated in a long arm cast with the elbow flexed at 90°, forearm in neutral rotation, and wrist slightly extended. Close follow-up within 7 to 10 days for repeat radiographs is essential to monitor for any loss of alignment, which requires urgent orthopedic referral. For displaced fractures, the classic "dinner fork" angular deformity (see images a and b) is most noticeable laterally and is indicative of the severity of the injury. Often, relatively good anatomic alignment is preserved in the anteroposterior (AP) plane; nevertheless, a prompt closed reduction is usually indicated to improve functional outcomes (images c–f). The most common complication of both-bone forearm fractures is loss of pronation and supination, which requires patients to adapt motion at the elbow and the wrist to compensate and can adversely affect an athlete's ability to successfully return to sports participation, particularly in overhead sports requiring full ROM of the elbow and wrist in the dominant arm.

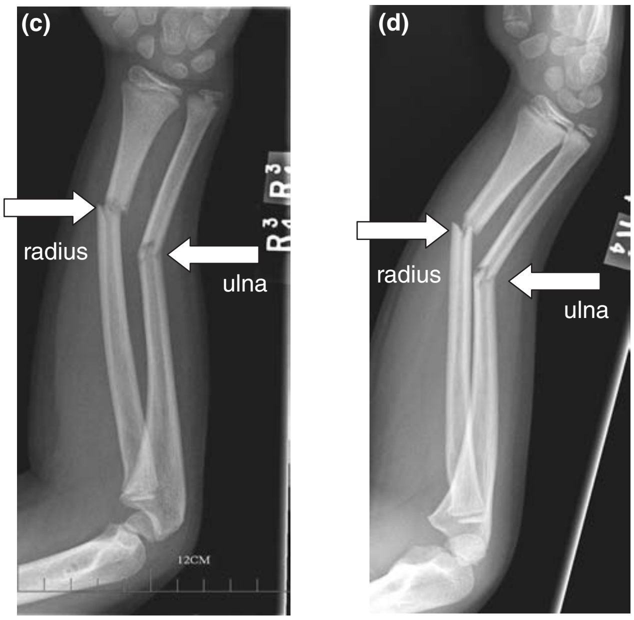
Complications

Complications of forearm fractures may occur at rates of up to 30%. Typical complications include malunion or nonunion, synostosis, reflex sympathetic dystrophy (complex regional pain syndrome), nerve injury, compartment syndrome,



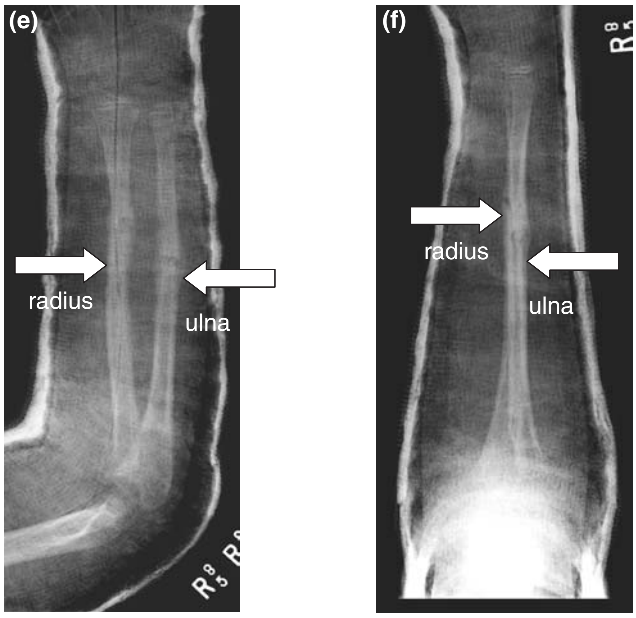
Radius and ulna in good anatomic alignment following closed reduction with conscious sedation. (a) Anteroposterior view; (b) lateral view. Radiographs were obtained after placement of the long arm cast.

Source: Photos courtesy of the authors.



Seven-year-old, right-hand–dominant male following FOOSH injury with displaced, midshaft both-bone forearm fracture. (c) Anteroposterior view; (d) lateral view.

Source: Photos courtesy of the authors.



Two weeks postreduction with good callus formation noted at fracture sites. (e) Anteroposterior view; (f) lateral view.

Source: Photos courtesy of the authors.

stiffness or decreased ROM, posttraumatic arthritis, musculotendinous injuries, heterotopic ossification, and/or refracture. All these are serious complications for athletes as weeks to months of rehabilitation may be required prior to any attempt to successfully resume sports participation.

Holly J. Benjamin and Brian Tho Hang

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Fractures

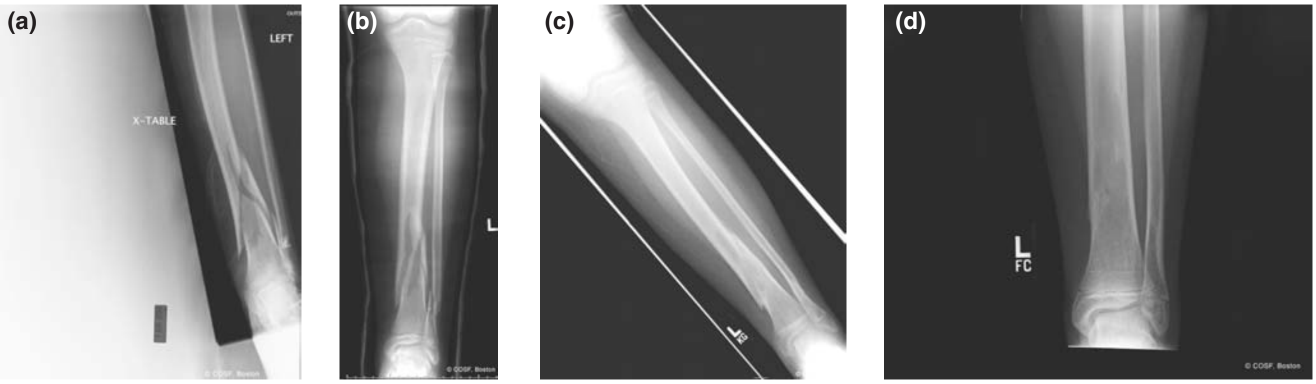
Fractures are breaks in bones. They are caused by trauma or overuse. This entry reviews the basic types of fractures, fracture healing, fracture treatment methods, and general outcomes.

Fracture Types

Fractures are described by their location, the degree of displacement, and whether or not the bone has broken through the skin. In lay terms, it is sometimes assumed that a break is more serious than a fracture; to a physician, both refer to the same thing. A fracture that is incomplete or not fully through the bone may be a stress fracture, which often results from overuse in the foot, leg, or hip of a runner, for example. A complete fracture that is fully through the bone may be described as either *nondisplaced* (hairline crack) or displaced (the two parts not aligned), ranging from minimally displaced to widely displaced. If a bone is broken into many pieces rather than cleanly, it is referred to as a *comminuted fracture*. The former term for a broken bone that has gone through the skin was *compound fracture*; now this is described as an *open fracture*. A fracture where the bone does not pierce the skin is a *closed fracture*. Thus, a person with an open, widely displaced, comminuted tibia fracture has a shinbone that is broken into many pieces, is badly out of place, and has gone through the skin.

Fracture Healing

Fracture healing varies by age, location, severity of the fracture, and treatment method. In general, children's bones heal much faster than those of adults. In a baby a long bone may heal in a few weeks, whereas in a 6-year-old child the same bone may take 6 weeks and in an adult 6 months to fully heal. When a bone fractures, first a blood clot forms, much like a scab forms on cut skin. Next, the cells in the blood clot recruit bone-forming cells (*osteoblasts*), which begin making new bone. At first, this bone is poorly organized and looks cloudy on an X-ray. This is called *callus*. Usually, enough callus is present to allow weight bearing by 6 weeks after the fracture. Over time, this new bone solidifies and reorganizes into a strong new bone. This is called *remodeling*. The process of remodeling takes from several months to several years after the injury. Images (a)–(d) on page 560 depicts a displaced tibia (shinbone) fracture treated with a cast and its progressive healing over the next 6 months in an 11-year-old boy. In children particularly, bones have wonderful remodeling properties. It is possible in a child to have a bone heal very crookedly and straighten itself out without help over time. It should be mentioned that good nutrition, in particular 400 international units



(a) Initial comminuted tibia fracture in an 11-year-old boy, (b) initial callus at 6 weeks, (c) able to walk independently at 3 months, and (d) bone well remodeled at 6 months and back to playing hockey

Source: Photos courtesy of Children's Orthopaedic Surgery Foundation.

(IU)/day of vitamin D and 1,000 milligrams (mg)/day of calcium, is very important for fracture healing.

Fracture Treatment Methods

Fracture treatment varies widely by the age of the patient and the severity of the injury. For some fractures, crutches or a sling may be all that is needed. For more severe fractures, surgery with a rod or plate and screw fixation may be needed. The following are the guidelines for fracture treatment.

Initial Treatment

The initial treatment when someone is injured should be to assess the injury and to stabilize the injured part, straightening it gently if it is bent or twisted. A removable stabilizing device called a splint is applied. If an open fracture is present, the bone should not be put back through the skin. Instead, a clean dressing should be applied as well as a splint and urgent transport to a medical center arranged. The limb below the fracture should be assessed for vascularity and nerve function by checking that the fingers and toes can move and are pink and warm. After initial immobilization, the patient should be assessed by a physician. Generally, X-rays are obtained, and sometimes, other studies such as computed tomography (CT) scans and magnetic resonance imaging (MRI) are done to find out what kind of fracture is present. Once the fracture has been properly diagnosed, treatment can proceed.

Definitive Treatment

Stress Fractures and Nondisplaced Fractures

These are generally treated nonoperatively with rest, protected weight bearing, and time. For example, a stress fracture (not out of place) in the foot usually needs a walking boot and crutches for 4 to 6 weeks. A complete but nondisplaced fracture in the leg may need a cast and no weight on it for 6 weeks or until healing callus is seen on the X-ray. A collarbone fracture that is nondisplaced would typically be treated with a sling and no lifting with that arm for 6 weeks.

Displaced Fractures

Fractures that are out of place generally need to be straightened (this is called *reduction*) and may need surgery. In children, displaced fractures can often be treated successfully with reduction and casting for 6 to 12 weeks depending on the child's age and the type of bone. In adults, many displaced fractures need surgical fixation for treatment. Fixation may range from pins (image e, page 561) to external fixators, where external pins attached to rings or a bar hold the bone in place (image f), to plates and screws (image g) to medullary rods, inserted down the medullary canal of long bones (image h).

Open Fractures

Fractures that come through the skin always need surgery to clean them. This is because they

(e)

Elbow fracture in a child treated with pin fixation

Source: Photo courtesy of Children's Orthopaedic Surgery Foundation.

(f)

Example of an external fixator holding the bone

Source: Photo courtesy of Children's Orthopaedic Surgery Foundation.

are at high risk of infection. After the surgical cleaning, the bones are fixed in the method most appropriate for the type of fracture.

Rehabilitation

On average, many fractures are healed enough by 6 weeks to allow weight bearing. However, it takes just as long to rehabilitate the fractured limb back to full function. Often, the rehab process takes at least as long as the bone-healing time. Usually, this involves physical therapy. A physical therapist is a person trained to guide a patient through exercising an injured part according to the physician's orders and aiding return of full strength and function.

(g)

Example of plate and screw fixation of a femur fracture

Source: Photo courtesy of Children's Orthopaedic Surgery Foundation.

(h)

Example of a medullary rod in a femur fracture with abundant callus (ball of bone) across the healing fracture

Source: Photo courtesy of Children's Orthopaedic Surgery Foundation.

Outcomes

After the fracture is healed, most patients return to a high functional level. Thus, most athletes who have sustained a fracture can expect to return to their sport. However, except for minor fractures, such as a toe fracture, it often takes 3 to 6 months to fully heal and rehabilitate a fracture.

Samantha A. Spencer

See also Avulsion Fractures; Carpal Fractures; Cervical and Thoracic Fractures and Traumatic Instability; Elbow Fractures; Finger Fractures: Bennett Fracture, Boxer's Fracture; Medial Epicondyle Avulsion Fractures of the Elbow; Pelvic Avulsion Fractures; Skull Fracture; Tibia and Fibula Fractures

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Friction Injuries to the Skin

Dermatologic injures are the most frequently encountered injuries in sports, with friction injuries accounting for the majority of skin problems in athletes. Friction injuries, such as abrasions, blisters, chafing, and calluses, occur when the skin is destroyed by physical shearing forces. Because sporting equipment is usually the primary cause of skin trauma, different sports cause friction injuries on various areas of the body. This entry discusses the most common friction injuries encountered in athletics and touches on the specific friction injuries seen in different sports.

Causes

Friction injuries occur from shearing forces applied to the superficial layers of the skin. The mechanical forces eventually lead to cellular damage and breakdown of the outermost layer of skin, the epidermis. These injuries can occur from acute traumatic forces applied to the skin or from chronic, repeated low-intensity forces. The feet and hands are the most commonly affected, but friction injuries can occur anywhere on the body. Improperly fitted sporting equipment, clothes, and shoes increase the risk for friction injuries.

Blisters

Blisters are very common among athletes. Repetitive shear forces lead to damage and separation of the internal layers of the epidermis, sparing the most superficial layer. This allows for fluid to collect and be contained between epidermal layers. Blisters usually occur on the hands and feet, where the thick skin can withstand repeated forces without sustaining significant damage to the outermost layer. Risk factors for blister formation include a moist environment, poor-fitting shoes or gloves, and sports requiring frequent changes of direction. Excessive moisture increases the frictional forces transmitted to the skin. Also, the frequent cutting or changes in direction that occur in sports such as soccer, basketball, and tennis place the skin of the soles in repeated shearing situations.

Blisters in uncommon areas such as the trunk or upper arms or legs should raise the question of an underlying connective tissue disorder such as pemphigus vulgaris or bullous pemphigus. These conditions are autoimmune disorders, where the body attacks itself within the layers of the skin, causing fluid collection and blister formation. Little friction is needed in this case to cause the blisters, and these can be debilitating diseases.

Treatment of blisters involves removing the enclosed fluid and protecting the outermost epidermal layer. Draining the fluid will allow the layers of the skin to heal more quickly. It is important not to damage the roof layer of the blister when removing the fluid as this layer is an excellent biological protective dressing. Then, covering the blister with a nonocclusive dressing that can protect it from recurrent frictional forces is also helpful. Prevention of blister formation involves wearing properly fitted shoes to limit excess friction and limiting excessive moisture buildup.

Calluses

Calluses are areas of thickened skin that develop in response to recurrent frictional forces. Unlike blisters, calluses are a more chronic condition, where the body responds to excessive friction by increasing the thickness of the superficial skin layers for protection. Calluses frequently occur in areas of prior blisters, and again the hands and feet are the most common areas for callus formation. Calluses are common on the soles of the feet of runners and on the palms of tennis players and rowers. Some athletes feel that calluses give them a competitive advantage because the thickened area of skin gives them increased protection from the more painful blisters that can occur.

Treatment of calluses involves paring down the thickened layers of skin with either a surgical blade or a chemical agent (salicylic acid). During this process, there should be no evidence of bleeding as blood vessels do not grow into the thickened skin layers, unlike in warts. Preventive measures to limit callus formation include limiting repetitive friction or protecting the area of skin with a barrier such as moleskin.

Chafing

Chafing refers to skin abrasions or erosions caused by repeated frictional forces either between two opposing layers of skin or between skin and clothing. Chafing occurs most commonly around the groin, underarms, and nipples but can also occur anywhere on the body. As with blister, chafing is exacerbated by moisture. Frequent friction between the inner thighs or between the chest wall and inner arms during running motions can lead to chafing. Also, a moist shirt repeatedly rubbing on a runner's nipples (jogger's nipples) can cause significant chafing in this area. The symptoms of chafing include pain, burning, bleeding, and scab formation.

Treatment of chafing is similar to care of open wounds. This includes avoiding repetitive frictional forces, limiting infection risk with antiseptics, and covering the area with a protective, breathable barrier. Decreasing friction can be done by applying a lubricant to the commonly affected areas of the body with either petroleum jelly or other commercially available lubricating products. Staying hydrated is also helpful as this allows the body to maintain sweat production and prevents salt crystals from forming on the skin that can increase frictional forces. Avoiding loose-fitting clothing, which can cause excessive rubbing over prominent skin areas, will decrease the risk of chafing as well.

Hemorrhages

Besides blisters and calluses, repeated trauma or friction from sports with frequent stopping and starting can cause toenail damage. With repeated contact between the great toe and the front inside surface of a shoe, the nail can be dislodged from the nail bed, and bleeding under the nail can occur. This is called a subungual hematoma and is commonly seen in tennis, soccer, basketball, skiing, and running. Over time, chronic disruption of the nail from the nail bed can lead to a dystrophic and thickened nail. Wearing shoes that have a wide toe box while fitting tightly around the midfoot can be preventive. Although this process is benign, subungual hematomas can be painful enough to limit participation in sports.

Another hemorrhage problem that can occur in the foot is on the lateral aspect of the heel. Repeated shearing of the epidermis on the underlying dermis can lead to small areas of bleeding between these two layers. This is referred to as "talon noir" or "black dot heel." Differentiating this entity from other more serious pigmented skin lesions such as melanoma is important. In talon noir, the small hemorrhagic areas can easily be removed by paring away the superficial layer of skin, whereas a melanoma cannot be removed this way. This lesion is benign and should not limit athletic participation.

Sport-Specific Injuries

Jogger's Nipples

Repeated rubbing of loose-fitting clothing can cause chafing and fissuring of a runner's nipples. This can occur in both males and females and can be quite dramatic if the rubbing erodes down into superficial blood vessels, leading to bleeding. Prevention involves wearing a well-fit jogging bra or soft shirt or by covering the nipples with a protective bandage.

Tennis Toe

Common in tennis but not limited to this sport, tennis toe refers to a painful subungual hematoma that usually affects the first or second toe.

Mogul Skier's Palm

This is another hemorrhagic condition where repeated planting of a ski pole leads to hemorrhage in the area just below the thumb. This is a self-limiting condition, and avoidance of continued palmar friction is the treatment, which usually occurs at the end of the ski season.

Pulling Boat Hands

This refers to blister and callus formation in the palms of rowing athletes due to repetitive frictional forces applied to the hands from oar handles. Over time, however, the callus formation may become beneficial.

Swimmer's Shoulder

This is an abraded area of the upper shoulder caused by repeated friction trauma in male swimmers. The cause is abrasive forces between an unshaven face and the skin over the shoulder. Regular shaving eliminates this irritation.

Runner's Rump

Frictional forces at the top of the gluteal cleft sustained during long-distance running can cause a localized area of bleeding. This is usually minimally painful and does not lead to any long-term complications. It is also self-resolving.

Rower's Rump

This condition is experienced by rowing athletes and involves an area of skin over the buttocks where the athletes sit on the boat seat for prolonged periods of time. This chronic irritation can lead to itchiness and thickening of the skin. Treatment involves changing to a padded seat.

John Hatzenbuehler

See also Black Nail; Blisters; Calluses; Irritant Contact Dermatitis; Jogger's Nipples

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Frostbite and Frost Nip

Outdoor athletes are faced with many challenges. In addition to dealing with the physical demands of their individual sports, outdoor athletes are also faced with the challenge of dealing with environmental conditions that can not only affect performance but also cause significant health issues. Exercising in the cold poses many such problems, and the skin, the largest organ in the body, can be seriously affected by cold exposure.

Frostbite is the most common dermatologic injury caused by cold exposure and will affect many athletes participating in outdoor winter sports. It is difficult to accurately estimate the frequency of frostbite or frost nip in the athletic population as many of the cases go unreported to coaches and trainers. Studies have reported that frostbite is seen most commonly in the 30- to 49-year-old age-group and is most common in the exposed areas, such as hands, feet, and face.

Frost nip is very common and is the precursor to frostbite. Frost nip involves freezing of the very top layers of the skin. Most athletes will become aware of this when someone else alerts them to the fact that their skin is slightly discolored, usually a bluish white color. Typically, there is a slight change in sensation in the skin, with some people complaining of mild numbness.

Deeper frostbite involves progressive freezing of the deeper layers of the skin. Typically at skin temperatures in the range of 37 to 50 °F (3–10 °C), the top layers of the skin begin to freeze, causing a decrease in sensation and slight swelling of the skin. If cooling continues, usually to temperatures of 5 to 21 °F (–15 to –6 °C), there will be deeper freezing of the skin tissue, leading to the formation of ice crystals inside and outside cells, with eventual cell destruction. This phase is usually accompanied by tingling of the affected area. As cooling progresses, the blood vessels become very leaky, and eventually the area of tissue will begin to die as the blood flow is essentially cut off. Frostbite of this severity is very rare but is seen with more frequency in high-altitude climbers. Deep frostbite is usually painful initially but then becomes painfree as the affected tissue becomes numb. The skin is pale, cold, firm, and rigid to touch.

The severity of deeper frostbite is usually not apparent until the thawing process begins. First-degree frostbite demonstrates mild numbness, redness, and swelling on exam. Blisters are not present. Second-degree frostbite results in clear blister formation along with redness and swelling. Third-degree frostbite has blood-filled blisters. Fourth-degree frostbite involves freezing down to the muscle and bone and will eventually result in loss of the affected tissue. It may take several days after the initial exposure to get a true sense of the severity of deeper frostbite.

Treatment

Treatment involves warming of the affected area, but this should not be done until the risk of refreezing has been eliminated. Repeated cycles of freezing and rewarming can actually cause more inflammation and tissue damage than leaving the affected area cool until definitive warming can be achieved. The affected area should be protected with splinting and elevation whenever possible, and the person should be transported to a warm environment immediately. As with any injury that occurs in the cold, care must be taken to not overlook the symptoms of hypothermia.

Definitive treatment involves removing cold and wet clothing and placing the patient in a sheltered warm environment. Frost nip can usually be treated adequately by removing the athlete from the cold and warming the affected body part with direct skin contact. Deeper frostbite is best treated with submersion of the affected body part in a warm bath, usually between 102 and 108 °F (39 and 42 °C), for 15 to 30 minutes. With severe frostbite, athletes may require pain medication as the affected area can become very painful with warming and the return of sensation. Blisters should be treated in a medical facility. Clear blisters are typically drained and covered with a clean dressing along with aloe vera. Blood-filled blisters are left intact and covered with a clean aloe vera dressing. Patients with severe deeper frostbite usually require antibiotic treatment to prevent infection. Most patients with significant deep frostbite should receive a dose of a nonsteroidal anti-inflammatory drug as soon as possible to decrease the amount of inflammation and the resultant tissue injury. There are other treatments that have been proposed for severe frostbite, including hyperbaric oxygen, tissue plasminogen activator, prostaglandin analogs, nifedipine, and other drugs; however, none of these have shown consistent benefit.

Prognosis

The long-term outcomes of frostbite depend on the severity of the initial injury. Frost nip has no long-term complications. With deeper frostbite, if the area has intact sensation and the color looks good, the likelihood of any long-term complications is very low. Skin that has blood-filled blisters, severe discoloration, and frozen tissue has a much higher rate of long-term sequela including decreased sensation, cold sensitivity, skin discoloration, and excessive sweating. In extreme cases, deep frostbite can cause nail abnormalities, early closure of growth plates in young children, and eventual loss of the affected digit.

Return to Sports

Return-to-play guidelines for athletes with frost nip or frostbite again depend on the severity of the exposure. Frost nip does not preclude returning to play, but any level of injury worse than this necessitates removal from competition or training. For frost nip, once the affected area regains normal color and sensation, the athlete may return to play with close observation. If symptoms recur, the athlete should be removed from play. With deeper frostbite, the athlete should be removed from play and treated as described earlier. As stated earlier, care should be taken to avoid repeated freeze and rewarming cycles, and as a result, athletes with deeper frostbite should not be allowed to return to play that day. Return to full play is subsequently guided by clinical healing. The affected part should have normal sensation and range of motion, and the skin should be healed of all blisters. Athletes need to be warned that they are twice as likely to get frostbite once they have had an initial frostbite injury.

Prevention

The prevention of frostbite involves protecting the skin from the cold and keeping the core warm. It is important to remember that heat loss is exacerbated by contact with metal, water/moisture exposure, and windy conditions. As a result, removing metal jewelry is recommended. Layering with good wicking materials will help pull moisture away from the skin and thus prevent excessive cooling. Keeping the core of the body warm and keeping the head covered will reduce rapid heat loss, allowing the extremities to stay warmer for longer. An external wind barrier can also assist in staying warm. Finally, paying attention to environmental conditions can also help prevent frostbite injuries. Athletes need to be aware that on cool, wet, windy days, they can still get frostbite even if the temperatures are not below freezing.

Athletes are faced with many challenges as they try to improve their abilities in various sports. Outdoor athletes need to take into account how the environment will affect not only their performance but also their physical health. Frostbite and frost nip are frequent ailments that outdoor athletes will run into, especially in the colder climates. With a little preparation and awareness of their surroundings, athletes should be able to recognize the early signs and symptoms of frost nip and, thus, prevent the more severe cases of deeper frostbite.

Mark Snowise

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Frozen Shoulder

Frozen shoulder is a descriptive diagnosis for a shoulder that has lost substantial range of motion. Usually, the term refers to an abnormality of the glenohumeral joint capsule where the capsule has lost its normal distensibility or to adhesions that have formed between the joint capsule and the head of the humerus. Typically, other structural reasons for loss of shoulder range of motion (e.g., glenohumeral arthritis, fractures, or loss of function of shoulder muscles) are not considered to be frozen shoulder. However, there can be substantial overlap between rotator cuff tendinopathy and frozen shoulder symptoms, especially early in the course of the disease, and it is common to confuse the two diagnoses.

Anatomy

The shoulder is a ball-and-socket joint with great freedom of movement. The head of the humerus is a relatively large ball, and the glenoid is a relatively small socket. The relationship between the two is commonly compared to a golf ball sitting on a golf tee. Because there are few bony restrictions on the motion of the humerus at the shoulder, the joint is typically very free moving, with approximately 180° of forward flexion and abduction and 90° of internal and external rotation. However, this freedom of movement also causes instability in the shoulder. Several redundant anatomic structures provide the shoulder with stability. The glenoid labrum is a ring of cartilage that extends from the rim of the glenoid and wraps around the head of the humerus. Outside the labrum is the shoulder capsule, a loose bag of synovium that defines the joint space and prevents extremes of motion. The glenohumeral ligaments are fibrous thickenings of the interior capsule wall that attach the glenoid to the humerus and provide the majority of the stabilizing properties of the capsule. Fifteen individual muscles and tendons cross the shoulder joint. Of these, four short muscles, collectively called the rotator cuff, contribute significant stability to the shoulder joint. When the rotator cuff muscles contract, they pull the humeral head onto the glenoid. In addition, they contribute to internal and external rotation and abduction of the shoulder.

Causes

Frozen shoulder is an idiopathic illness. It occurs most commonly among women between the ages of 30 and 60 years. Apart from age and sex, having diabetes mellitus is the strongest risk factor for frozen shoulder. Occasionally, it occurs in patients who have had shoulder pain or loss of function due to other pathology, such as rotator cuff strains or tendinosis, fracture, paralytic stroke, or seemingly minor trauma. Whether or not these ailments contribute to the development of frozen shoulder is controversial. Rarely, thyroid disease, Parkinsonism, or antiretroviral medications (e.g., for human immunodeficiency virus [HIV] infection) can be associated with the development of frozen shoulder. Some authors have argued that patients with low pain thresholds or poor compliance with physical therapy exercises seem to be at higher risk, but this is not well established. Using a shoulder or arm sling can also lead to frozen shoulder if it is used for too long. Typically, 1 to 3 days of shoulder immobilization following injury is safe. More prolonged shoulder immobilization should be accompanied by at least daily shoulder range of motion or pendulum stretch exercises if they can be safely performed.

Symptoms

Frozen shoulder typically follows a three-phase progression. The "freezing" phase is marked by significant shoulder discomfort and progressive loss of range of motion. This phase is also sometimes called the "painful" phase. The pain may be due to coincident shoulder pathology, such as rotator cuff tendinopathy, but is usually intrinsic to idiopathic frozen shoulder. The freezing phase typically lasts 3 to 9 months. The "painless frozen" phase consists of continued restricted range of motion but markedly reduced pain. Patients are often quite satisfied with their progress during this phase despite continuing to have poor range of motion. The painless frozen phase typically lasts for 3 to 6 months. The final phase is commonly called the "thawing" phase as improved range of motion spontaneously returns to the shoulder. This phase typically lasts for 3 to 9 months. The entire course of frozen shoulder can last for 15 to 24 months.

Diagnosis

The diagnosis of frozen shoulder is made based on history and physical examination. The hallmark feature of the condition is a palpable block to range of motion that is not due to a bony abnormality or pain. Patients have at least a 50% reduction in shoulder range of motion, with loss of both active and passive motion. Close inspection is required to ensure isolation of the glenohumeral joint when evaluating range of motion. The examiner can be fooled into thinking that the patient has near-normal motion if he or she is able to compensate for his or her tight glenohumeral joint with scapulothroacic movement. No diagnostic imaging is needed to make the diagnosis of frozen shoulder, but it is common practice for medical providers to order X-rays to assess for bony abnormalities and/or magnetic resonance imaging (MRI) to assess the integrity of the rotator cuff muscles and glenoid labrum. Thickening of the capsule and synovium can be seen on the MRI scan in both idiopathic frozen shoulder and frozen shoulder due to other pathology. If an arthrogram of the shoulder joint is performed, it is common to see a decrease in volume of the glenohumeral joint. This represents contracture and loss of elasticity of the joint capsule.

Treatment

If a patient's frozen shoulder is due to an underlying abnormality (e.g., a complete rotator cuff tear, fracture, or nerve injury), this cause must be addressed first. It can be very difficult for a patient to recover shoulder range of motion in the face of other significant shoulder pathology. For idiopathic frozen shoulder and frozen shoulder due to abnormalities not amenable to surgical correction, the most commonly prescribed treatment is physical therapy. The goals of therapy during the painful phase are to protect the shoulder joint and slow loss of function. During the painless and thawing phases, therapy consists of progressive stretching to increase range of motion and restore function. There are few data to support this practice, but most medical providers think that it is unlikely to do harm, and there are clearly some patients who respond well to physical therapy. Also, a well-trained and thorough physical therapist may pick up on other shoulder abnormalities that were not noticed during the initial medical evaluation.

Other commonly prescribed treatments during the painful phase include a course of nonsteroidal anti-inflammatory drugs (NSAIDs) or oral corticosteroids, such as prednisone. These medications do provide some short-term relief of the symptoms but do not seem to affect the overall course of the condition, and relief generally does not last more than 6 weeks.

Corticosteroid injection of the subacromial space does provide relief and may decrease the duration of symptoms in patients who have underlying rotator cuff or biceps tendinosis. In the absence of these conditions, corticosteroid injection may improve shoulder pain and mobility for several months following the injection, especially if combined with supervised physical therapy. However, there seem to be no long-term benefits of corticosteroid injection for the treatment of frozen shoulder.

Intraarticular dilation (hydroplasty) is a procedure that can be performed in the primary care setting for patients with frozen shoulder. It involves placing a needle or catheter in the shoulder joint and using saline and a small amount of corticosteroid to distend the shoulder capsule. The procedure is often done with radiographic verification of needle placement and injection of contrast material to confirm intraarticular injection. Initial studies of this technique have provided encouraging results. Patients with severe and persistent symptoms who undergo hydrotherapy report decreased pain and improved range of motion as early as 3 weeks after the procedure, and benefits seem to persist for the duration of the illness.

Shoulder surgery is reserved for patients who have had prolonged and severe symptoms and have not had improvement with more conservative measures. Surgery should never be considered as first-line therapy, because it can aggravate the symptoms, prolong the course of the illness, or precipitate a bout of reflex sympathetic dystrophy in some patients. Surgical therapy is aimed at stretching or releasing the contracted joint capsule. There are two techniques that are commonly used. Sometimes, they are both done at the same time. The most common surgical technique for frozen shoulder is manipulation under anesthesia. The patient undergoes general anesthesia and paralysis to relax the muscles of the shoulder. The surgeon forces the shoulder joint through an increased range of motion, stretching or tearing the tight capsule. Arthroscopy may be performed at the time of manipulation or separately. The surgeon will insert a small camera and instruments through small incisions in the skin and shoulder. Small cuts are placed in the joint capsule to allow it to distend. Following surgery, it is important for the patient to continue with physical therapy in order to preserve any gains in motion obtained with surgery.

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See also Musculoskeletal Tests, Shoulder; Shoulder Impingement Syndrome; Shoulder Injuries; Shoulder Injuries, Surgery for

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Functionally One-Eyed Athlete

Eye injuries are common in athletes, and they often can be very devastating injuries. In the

United States, eye injuries occur most commonly in baseball and basketball. Any sport with a ball or a striking object increases the risk for a possible sports-related eye injury. Eye injuries are easily preventable so long as the proper protective equipment is used.

In the United States, sports-related eye injuries are second only to occupation-related eye injuries. Eye injuries are the leading cause of blindness in children in the United States, and many of these injuries are sports related. According to the National Eye Institute, these injuries account for an estimated 100,000 physician visits per year at a cost of more than $175 million.

Classification and Mechanisms

Eye injuries can be classified as blunt trauma, penetrating trauma, or radiation injury. Blunt trauma can be further classified by the anatomic location in which the injury occurs (anterior chamber, posterior chamber, and orbit and adnexa).

The type of injury that occurs depends on the equipment used in the sport, the playing field/court, and the rules of the game. For example, the injuries to the face and eye from a small, hard ball (e.g., a golf ball) are different from those imparted by a larger, deformable ball (e.g., a soccer ball). Also, the nature of soccer, with the ball often coming from the ground up to the face, will lead to different injuries than if a ball were to come from a higher elevation down toward the eye, because the forehead and the bony orbit are better able to protect the eye in the latter scenario.

Different injuries can also result from the different playing venues. Racquetball and tennis are both racquet sports, but in racquetball the athletes share the same playing space, whereas in tennis the net divides the playing surface. Therefore, the risk of hitting your opponent with the racquet is much higher in racquetball than in tennis.

Definition

Severe eye injuries can lead to permanent impairment of vision. If an athlete has an underlying severe visual impairment, an injury to his or her good eye could lead to a permanent visual disability. This type of athlete is considered functionally one eyed. If there is an injury to the initially unaffected eye, the person can be severely impaired for the rest of his or her life, and the injury could leave the athlete permanently blind. Some ophthalmologists use a cutoff of best-corrected vision in the poorer eye of 20/40 or 20/60 to determine if someone is functionally one eyed. This means that the "bad eye" can only be corrected to 20/40 or 20/60 at the very best. This leaves the athlete with only one "good eye." If this good eye were to be injured, it could leave the person permanently disabled.

Clearance to Play

The functionally one-eyed athlete should consult an ophthalmologist prior to playing any sport. The athlete will be counseled to use protective eyewear at all practices and all games. This includes sports with other protective equipment. For example, acceptable eyewear should be worn under a standard football helmet. These athletes also should be made aware that even recreational "pickup" games are not immune from possible injury and that protective eyewear must always be used.

Certain sports do not have proper protective eyewear available (e.g., martial arts, boxing, wrestling); therefore, the athlete should not compete in these events.

Eyewear

Acceptable protective eyewear is usually molded frames of a single piece with at least a 2.5-millimeter polycarbonate lens. Ordinary eyeglasses do not offer adequate protection to the eye, often because the lens is not shatterproof and also because the frames are not strong enough to withstand the forces of sports. They should pass the ASTM (American Safety Testing of Materials) guidelines for use in sports.

Nilesh Shah

See also Craniofacial Injuries; Eye Injuries

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Fungal Skin Infections and Parasitic Infestations

Fungal skin infections and parasitic infestations are common among athletes who participate in sports requiring close physical contact. These infections are quite contagious, and widespread outbreaks can occur if athletes continue to participate in sports without proper treatment. Most of these infections can be treated with topical medications, although some may require oral medication. Athletes who participate in sports at the high school and collegiate levels may be restricted from returning to activity until they complete a minimum period of treatment.

Fungal Infections

The organisms responsible for causing fungal skin infections are called *dermatophytes*. These organisms are found in soil, on animals, and on humans. Dermatophytes are spread by direct contact with an infected person or animal or by contaminated soil. Fungal infections are typically named based on the location of the infection rather than using the name of the causative organism. Fungal skin infections affecting the scalp and hair are called *tinea capitis*. *Tinea corporis,* also known as "ringworm," refers to fungal infection of the skin of the body. *Tinea cruris* or "jock-itch" is a fungal skin infection in the groin. The term *tinea pedis,* or "athlete's foot," is used for fungal infections of the feet.

Clinical Manifestations

The appearance of fungal infections depends on the location on the body. Tinea capitis often appears as a round patch on the scalp, with hair loss and a gray scale on the lesion. Ringworm on the body also has a round appearance, with a red raised border and a flat central area that may be scaly or flaky. Tinea cruris is characterized by bright red scaly lesions on the inner thighs and groin area. The appearance of athlete's foot may vary, but a common presentation is redness and scaling on the soles of the feet or between the toes. The red scaly skin of athlete's foot may also appear moist or weepy. Itching is a common complaint with fungal skin infections.

Diagnostic Testing

The diagnosis of a cutaneous fungal infection is often made by clinical appearance alone. However, cutaneous fungal infections can often be mistaken for other skin conditions such as psoriasis, impetigo, lichen planus, and seborrheic dermatitis. A simple, office-based diagnostic test with a potassium hydroxide (KOH) preparation can be done to confirm the diagnosis of fungal infection. Additionally, a fungal culture can be performed to confirm the diagnosis. The potassium hydroxide preparation is made by taking a small amount of scale from the lesion and placing it onto a microscope slide. The potassium hydroxide solution is then added to the scale, and it is examined under the microscope. If there is indeed fungus present, then characteristic hyphae will be observed.

Treatment and Side Effects

Athletes with cutaneous fungal infections can be treated with a variety of topical or oral medications. Many of these products are available over the counter, but some are available only by prescription. Oral treatment regimens are often associated with more side effects than topical regimens.

Topical regimens for tinea corporis and tinea cruris typically call for the application of a fungicidal cream such as terbinafine, ketoconazole, or clotrimazole once or twice daily for 2 to 4 weeks. Oral treatment regimens for tinea corporis and tinea cruris using griseofulvin, itraconazole, or fluconazole involve once-daily medications for 2 to 4 weeks. Relapses or recurrences of fungal infections are common, particularly if the athlete failed to complete the full treatment regimen.

Certain fungal infections require either longer topical treatment courses or treatment with oral agents. Tinea pedis requires longer topical treatment regimens than are used for tinea corporis or tinea cruris. Terbinafine, tolnaftate, and clotrimazole are commonly used over-the-counter agents for tinea pedis. These topical treatments are effective but require treatment courses of 4 to 6 weeks. Treatment of tinea capitis requires an oral regimen as topical treatment is ineffective. Most clinicians prescribe a 6-week course of griseofulvin to treat tinea capitis. Shorter treatment regimens are possible if itraconazole or fluconazole is prescribed.

Most of the topical agents used to treat fungal skin infections do not induce many adverse effects. However, the oral agents used to treat tinea capitis and tinea pedis do commonly cause side effects. Griseofulvin commonly causes mild side effects such as headache, photosensitivity, and rash. More serious effects such as liver damage, numbness and tingling, and reduction of white blood cell counts can occur in patients treated with oral griseofulvin. Doctors may order blood tests to monitor patients being treated with oral antifungal medications.

Return to Sports

Athletes who participate in high school and collegiate sports are commonly held from practice and competition until they have received adequate treatment for their infection. The National Federation of State High School Associations (NFHS) recommends that athletes with tinea corporis complete 1 week of treatment with an oral or topical agent before being allowed to return to sports. The National Collegiate Athletic Association (NCAA) recommends a minimum of 3 days of treatment before returning to play. Additionally, the NCAA requires that all lesions be covered with an occlusive bandage once the athlete returns to competition.

Parasitic Infestations

Parasitic infestations are not as common among athletes but are problematic when they arise. The two most common forms of parasitic infestation are *pediculosis capitis,* commonly referred to as head lice, and *pediculosis corporis,* commonly termed scabies. Both head lice and scabies are most commonly transmitted via direct contact with an infected individual. Head lice can be transmitted via shared combs, hats, and brushes. It is possible to contract scabies from infested bedding, but this is uncommon. Both conditions are common problems among people living in overcrowded conditions.

Clinical Manifestations

Head lice may produce itching of the scalp in the infected individual. Other symptoms associated with head lice are uncommon. Signs of head lice include the presence of nits and live lice visualized on the scalp. Scabies typically produces a very itchy reaction, with red linear burrows present on the skin. The burrows of scabies are often found between the fingers, at the wrists, in the armpits, and in the groin. The itching associated with scabies is most intense at night.

Diagnostic Testing

The diagnosis of head lice is typically made by directly observing lice and nits on the head. Nits are typically found at the base of the hair shaft, close to the scalp. Microscopic evaluation of lice and nits are typically not necessary. Similarly, the diagnosis of scabies is most commonly made based on the typical clinical appearance of the burrows and the patient's history. A scabies preparation can confirm the diagnosis through microscopic analysis of scrapings taken from the burrows, revealing lice, eggs, and fecal matter.

Treatment and Side Effects

Medications and local environmental controls are keys to effectively treating head lice and scabies. The treatment of choice for head lice is permethrin, available over the counter as a 1%-cream rinse. It is applied to hair that has been shampooed and towel dried and is left in place for 10 minutes before rinsing. The treatment can be repeated in 1 week if live head lice are still observed. Lindane 1% is a prescription shampoo that can be used in a similar fashion. Malathion is available as a 0.5% lotion, which is applied to the hair and left on for 8 to 12 hours before rinsing. In addition, most physicians recommend removing nits from the scalp by using a fine-toothed nit comb on wet hair. Bed linens, pillows, and hats should all be washed as well. Most clinicians recommend treating family members who share a bed or otherwise have close contact with the affected person.

Scabies is typically treated in a similar fashion. Topical treatment with lindane, malathion, or permethrin creams or lotions can be effective. The creams are applied from neck to toes in affected patients, generally at night, and rinsed off the next morning. Oral treatment with ivermectin can be used for recalcitrant or widespread cases. Most medical providers treat all household contacts of patients presenting with scabies.

Lindane has been linked to adverse events, including neurotoxicity, seizures, and, rarely, death. These adverse events are more commonly observed in children. As a result, many practitioners do not regularly prescribe lindane. The use of lindane was banned in California in 2002 due to concerns over water contamination with lindane.

Return to Sports

NCAA requires that athletes, particularly wrestlers, be free of parasites prior to competition. They require patients with head lice to be appropriately treated and reexamined for effectiveness of therapy prior to returning to competition. Athletes with scabies must be treated and must have a negative scabies preparation on the day of competition. The NFHS allows athletes to return to competition 24 hours after an appropriate course of treatment for head lice and scabies.

Michael Pleacher

See also Dermatology in Sports; Skin Disorders Affecting Sports Participation; Skin Infections, Bacterial; Skin Infections, Viral; Skin Infestations, Parasitic

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Future Directions in Sports Medicine

The future of sports medicine holds more promise for radically improving the lives of patients than perhaps any other field of orthopedic surgery or primary care. Sports medicine focuses on the prevention, diagnosis, and treatment of athletes, predominantly for injuries involving the soft tissues (ligaments, tendons, menisci, and cartilage). Sports medicine has already clearly demonstrated the major benefits of a team approach to the care of patients—a team that includes players from the daily environment of the patient to the most complex medical care. These teams of patient, family, coach, certified athletic trainer, physical therapist, surgeon, and physician have long been a successful example of why continuity of care is so critical to a successful outcome—a principle that is only now being recognized by other fields of orthopedics and medicine. This team approach will continue to be a cornerstone of sports medicine in the future.

The future of sports medicine will also be one in which many injuries commonly seen today will be prevented, and when they do occur, diagnosis will be accurate and rapid and treatment even more successful than with the excellent options already available today. Possible key improvements in each of the areas are outlined in the paragraphs that follow. Undoubtedly, other advances that we cannot even imagine today will also contribute to the ongoing and continual advancement of sports medicine.

Injury Prevention

A 1999 estimate of injury rates in the United States indicated that each year approximately 550,000 patients rupture their anterior cruciate ligament (ACL; a major stabilizer of the knee), 400,000 tear a rotator cuff, 600,000 have injuries to the meniscus, and 600,000 damage their articular cartilage. The numbers of these injuries are believed to have increased since that time in proportion to increased participation in sports and exercise activities. It has also been estimated that the number of patients suffering from overuse injuries (e.g., tendinitis, plantar fasciitis, and epicondylitis) is more than 10 times greater than those numbers. Among the major advances in sports medicine will be the prevention of many of these injuries—both acute and overuse injuries. This will be the result of the increased understanding of injury mechanisms and the relationship between injury occurrence and epidemiologic factors such as gender, age, and body mass index. In addition, a more individualized approach, where both alterable and intrinsic factors are assessed, will also likely become routine practice. Assessment of intrinsic individual factors, including improved understanding of the effects of physical parameters (e.g., ligamentous laxity, knee valgus, lumbar lordosis), will be combined with the risk of injury in certain sports (e.g., ligamentous laxity with swimmer's shoulder; knee valgus with ACL injuries, lumbar lordosis, and spondylolysis) to create an athlete risk profile for activity in general, with additional sport-specific information. These risk profiles will be enhanced with the use of genetic markers for traits such as wound-healing capabilities, subtle collagenous defects, neuromuscular coordination, bone mass, and even tendon or ligament strength. In addition to these intrinsic, or unchangeable, factors, an even more exciting development will be the improved understanding of how factors that are variable and changeable can be enhanced to decrease risk for individuals. These alterable factors will become of paramount importance and will include learning and applying the knowledge gained for an individual during a gait analysis (hyperpronation as a simple example), with an assessment of the individual's muscle flexibility, and combining these pieces of information with the information on injury avoidance for a specific sport to design an individualized training regimen that will help athletes minimize the risk of injury. For example, a sprinter could have a gait analysis and physical exam in the off-season that might identify hyperpronation, decreased quadriceps strength, and decreased hamstring flexibility. The athlete could then be counseled to hold off on a full sprint until hamstring flexibility is improved in order to minimize the risk of a hamstring pull or to minimize stair training until the inner quadriceps is strengthened enough to allow for this without aggravating the patellofemoral joint.

For each athlete, all this will evolve into an individualized approach, whereby an individual deciding on which sport to pursue will be able to "test" for sports with performance of simple tasks (running, jumping, and physical demonstration of flexibility and laxity), a genetic screen for known associated factors, and quantified observation of sport-specific skill performance (landing a jump) and will be able to have an "athletic aptitude profile" that details the current state of the athlete's strengths and weaknesses and his or her overall aptitude for a given sport or a selection of sports. This would be similar to a career aptitude test administered to high school students considering a career choice. Athletes would thus not only have information that might allow them to make choices between a less risky and a more risky sport but also, most important, be able to determine which alterable factors they could improve to lessen their chances of injury. Clinics designed to address the common alterable factors, similar to the neuromuscular training programs designed to decrease the risk of ACL injuries in women, will become more widespread and begin to address common problems such as shoulder instability, rotator cuff injury, and even osteoarthritis. Web-based information will enable individualized analyses to be made accessible to all, and subsequent teaching of skills to lessen risk will also be available to the individual through the web, as well as with physicians or certified athletic trainers (ATCs) or physical therapists.

Prevention of overuse injuries will follow a similar trend, with children playing baseball having a screening of their throwing technique, and correction of technique will be possible in real time before the joints are stressed to the point of injury. This, in combination with an increased knowledge of the effect of training on the individual's body, will allow coaches and ATCs on the field to assess when an athlete is at risk of developing an overuse injury and will make this possible much before the onset of pain in the player.

Overall physical screening for all athletes from middle school onward will help identify any problem areas and perhaps use individualized training to help avert both acute and overuse injuries. In an ideal case, this screening will become part of the physical education program in our school system, but an interim step may be the conduct of these screenings in local sports medicine and physical therapy settings.

To realize the potential of these individualized injury prevention programs, much research into the influence of gait, kinesiology, strength, flexibility, fatigue, and training methods must be successfully conducted. Additional work in the long term on the influence of genetic factors on injury risk will further refine and improve these programs.

Diagnosis

In the future, the diagnosis of musculoskeletal injuries will be faster, easier, and more reliable. Current methods of diagnosis hinge on careful history taking and physical examination. This will continue, but additional tools will be available to make both these analyses even more accurate and informative. Cohort studies and research into identifying risk factors for injury will provide great input and value to the history taking by the physician, ATC, or physical therapist. For example, cohort studies that identify history factors for ACL injury may include the patient hearing a "pop" or the timing of swelling, which will help the clinician determine whether the risk of an ACL tear is particularly high in a particular patient. Physical examination findings will also be assisted by similar studies; the predictive values of special tests for shoulder injuries, labral tears, and meniscal injuries will have greater clarification in the future. Gait labs will be more common and generally available to provide information on gait changes with early osteoarthritis or meniscal or labral tears. These data would assist with more rapid diagnosis of these and other entities.

Supplemental tests to the physical exam and patient history will include additional noninvasive measures. Handheld imaging devices will be available for office use. Office-based ultrasound is already being used to confirm diagnoses of tendinopathies and acute injuries. Additional handheld noninvasive imaging instruments that will provide even clearer pictures of structures below the skin will be developed. This will allow for speedier diagnosis of common problems such as stress fractures (and will assist with differentiating these from periostitis or shin splints). The resolution of both handheld and larger imaging devices will be improved as well, allowing clinicians to detect injuries on a microscopic level, as opposed to only being able to diagnose complete tendon or ligament disruption. Imaging techniques will also allow for functional assessment of living or dead cells within tissues, providing information about the extent of damage for tendinopathies and to help direct therapies for these entities. Currently, we have imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI). These techniques are useful in defining the anatomical features of the knee in a noninvasive way, and the resolution of these scans continues to increase and will likely continue to do so. The future likely holds use of these noninvasive measures to predict outcome and, more important, function—for example, the use of MRI or a similar modality to measure the strength of an ACL graft, the use of delayed gadolinium-enhanced magnetic resonance imaging of cartilage (dGEMRIC) or other special techniques to evaluate the status of the cartilage at the time of injury as well as after injury. High-resolution MRI and dGEMRIC or other techniques to help assess the functionality and viability of tissues such as cartilage, ligament, meniscus, and bone will become excellent adjunct tools for the clinician in diagnosing and treating injuries of these types.

The use of handheld imaging devices in the physician's office will also be extremely helpful in guiding injections into joints or injured tissues. With imaging assistance, smaller needles can be used and drug delivery to specific areas of injury can be performed. With the addition of monitoring for cell viability, the efficacy of treatments can also be monitored.

In addition to local imaging of pathology, there will be improved systemic markers for diseases including osteoarthritis, septic arthritis, stress fractures, and overuse injuries. These markers will be identified in the blood initially. Noninvasive methods for detecting the blood levels of these markers (e.g., light-scattering techniques) will be developed. In addition, these markers will also be detected in the urine, which would provide another noninvasive way of detecting disease and following its progression.

Evidence-Based Medicine

The future of sports medicine starts at the "bedside," with an improved understanding of how effective the current treatments of sports medicine problems are and what factors influence the likelihood of having a positive response to a treatment. For example, ACL reconstructive surgery in general is a very successful procedure—there is an excellent chance of patients getting back to their sports activities. However, some patients have more trouble than others. Determining the risk factors for a good or poor outcome is thus important to help advise patients about treatment options. One can imagine that the risk factors that might influence the outcome of a surgery could include body weight, activity level preoperatively, gender, or age. Not only is learning how these factors may affect outcome critical to predicting outcomes, but if the risk factors are modifiable (e.g., smoking), then patients can also be counseled as to what changes in lifestyle they could make to improve their outcomes of treatment.

To define the risk factors for a good or poor outcome, cohort studies are the most useful study design. Cohort studies are those that follow a group of patients after an injury or treatment. At the beginning of the study, data on the patients are collected—their age, gender, activity level, knee symptoms, and weight, among other informational items. Then, the group is followed, and outcomes are assessed at different time points. For example, patients with an ACL injury have the preoperative information, and then data on outcomes are collected at 1, 2, 5, and 10 years after surgery. Scores for how well patients are doing are correlated with the preoperative data, and the investigators can see which preoperative factors influence the outcomes. The Multicenter Orthopaedic Outcomes Network (MOON) is one such study looking at ACL reconstruction outcomes. Additional studies of revision ACL reconstruction (the Multicenter ACL Reconstruction Study, or MARS) and meniscal tear are also under way. The results of studies such as these will help orthopedists determine how to counsel their patients about risk factors and modifiable behaviors.

In addition, understanding how patients recover after a procedure should guide research in sports medicine. For example, some types of rotator cuff repair fail at a relatively high rate. This makes it an important clinical problem and should stimulate research into determining why these repairs fail and what can be done about it.

Treatment of Injury

While there are a lot of areas that will certainly grow and develop in sports medicine over the next decade, one of the most exciting areas will be stimulating tissues to heal better and faster. This revolution will be grounded in the science that is currently improving our understanding of many of the key musculoskeletal tissues involved in sports medicine injuries—ligament, tendon, meniscus, and cartilage. Improved understanding of how these tissues respond to injury and surgical treatment will lead to newer and more effective strategies for caring for patients with these injuries. A few examples are presented here.

Anterior Cruciate Ligament Injuries

Recent work has demonstrated that the ACL, which is located inside the knee joint, may have trouble healing after injury due to the synovial fluid environment breaking down the repair tissue between the two ends almost before it can form. This new understanding is leading to multiple investigators around the world working on ways to stabilize the wound site of the ACL with a scaffold that can stimulate healing of this important ligament after injury. Research is still preliminary, but the importance of stimulating healing of the ACL, and other tissues inside joints, such as the meniscus, is being recognized, and additional resources are being applied to find a solution to this very important problem. In the future, patients with an ACL tear may have the option of having their ligament repaired by using a biologic, injectable scaffold to stimulate healing—a procedure that could be less invasive than the current procedure used to treat these injuries.

Rotator Cuff Tears

Rotator cuff tears also often require surgical treatment for healing. Work currently being conducted on the biology of the tendon and the accompanying muscle atrophy that can occur after a rotator cuff tear will likely guide development of new strategies to improve the effectiveness and success rate of rotator cuff repair. For a long period of time, there has been no animal model available where the rotator cuff will not heal after injury (as occurs in the human condition). Recently, progress has been made on developing an animal model that has a similar ineffective healing response after a rotator cuff tear, and the successful completion of the development and validation of this model will greatly facilitate testing and speed development of new candidate procedures and biologic scaffolds purported to enhance healing in an animal model.

Thus, the development of this model is of paramount importance to moving the quest for improved rotator cuff repair ahead.

Meniscal Repair

Today, only a select group of meniscal tears can be repaired, and most meniscal tears are treated by removing the injured tissue (called a partial meniscectomy). Patients who have to have their whole meniscus removed due to symptomatic meniscal damage have an increased risk of osteoarthritis. It is not known if partial meniscectomy will have the same effect or how much meniscus can be safely removed without the patient having an increased risk for osteoarthritis. Future work on scaffolds that can be implanted to serve as a template for meniscal regeneration (replacement implants) and adhesive materials that can facilitate healing of tears that are currently thought to be irreparable (e.g., tears in the inner third of the meniscus or radial tears) may enable surgeons to preserve more meniscal tissue, and in turn, it is hoped that it may help avoid the accelerated osteoarthritis associated with complete meniscal loss. Research on enhancing meniscal repair and regeneration is currently hampered significantly by the lack of a validated animal model for meniscal tears. Without animal testing, it is difficult to test new candidate materials and techniques, and thus, even new techniques that look promising in the test tube can't be tested to learn more about how they might behave in a human knee.

Cartilage Repair

Currently, most cartilage repair is attempted only for relatively small and well-defined defects; larger defects are treated with replacement of large sections of bone and cartilage with either plugs or pieces of bone and cartilage obtained from a donor (osteochondral allografts) or from another site in the same patient, or by metal and plastic, as is done in a partial or total joint replacement. In the future, new biomaterials that encourage cartilage cell ingrowth from the remaining cartilage may help physicians successfully stimulate repair of larger lesions. In addition, techniques aimed at filling in the fissures seen in chondromalacia, and essentially resurfacing of the cartilage, will continue to be of great interest both on a basic science level and in the treatment of patients.

Summary

In summary, the future of sports medicine is extremely bright. With the continuation of the team approach to patient care, many advances will occur. In the future, the majority of injuries we see today will be prevented. For the injuries that do occur, our ability to diagnose the injuries will be improved in both accuracy and speed. A greater understanding of risk factors for outcomes after injury or surgery will also enhance our ability to advise and counsel patients. New, improved, and less invasive treatments will continue to be developed to make the burden of a sports medicine injury as low as possible for patients. The improvements outlined here, and the many improvements that one cannot even yet anticipate, will ensure that sports medicine continues its vibrant culture of "bedside to bench" research and continual advancement in the care of patients.

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See also Careers in Sports Medicine; History of Sports Medicine; Sports Injuries, Surgery for

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Gastrointestinal Problems

Gastrointestinal problems are common in the general population, including athletes. Athletes are also at increased risk for traumatic abdominal injuries.

Motility Disorders

Gastrointestinal motility disturbances affect a significant number of recreational and competitive athletes. Runners report symptoms more frequently than other endurance sports athletes; hence, the term *runner's trots* is used to describe the stool changes that have been associated with running. Motility disturbances manifest through a variety of gastrointestinal symptoms, including nausea, vomiting, bloating, cramping, urge to defecate, or change in frequency of bowel movements. Lower gastrointestinal symptoms are noted more frequently than upper gastrointestinal symptoms, especially in female athletes, likely due to hormonal changes of the menstrual cycle. Deconditioning in the untrained athlete also seems to lead to increased symptoms.

The precise etiology of gastrointestinal motility disturbances with exercise is unclear. Some theories suggest that muscle enlargement during exercise causes compression of the colon, while others point to decreased blood flow to the colon during exercise resulting from the greater blood flow to the muscles. Other theories identify mechanical and hormonal changes as causing altered transit time of material through the gastrointestinal system. Most likely, the etiology involves multiple factors that may be influenced by the intensity of exercise and hydration status.

Symptoms typically occur during or immediately following exercise and may involve a range of symptoms from abdominal cramping to severe diarrhea with incontinence. A complete history should review any recent travel or unusual food consumption to evaluate for an infectious cause. Symptoms that are not related to exercise activity should raise suspicion for an underlying disorder such as inflammatory bowel disease or irritable bowel syndrome. Evaluation and testing should be directed based on the history and exam findings as well as on the concern for etiology other than exercise. Treatment should emphasize rest until symptoms resolve, as well as proper hydration. Gradual return to exercise is recommended when the symptoms resolve. Antidiarrheal agents should be used with caution as they may increase the risk of heat injury. Avoidance of substances that may worsen symptoms is recommended. Foods high in fiber and fat as well as milk and fruits should be avoided for a few hours before exercise. Protein and herb supplements have also been associated with increased symptoms. Symptoms may be alleviated with bowel and bladder emptying before exercise.

Gastroesophageal Reflux Disease (GERD)

Gastroesophageal reflux disease (GERD) is a condition where the stomach (gastric) contents move up into the esophagus (the muscular tube from the throat to the stomach). The characteristic symptoms include heartburn and acid indigestion, but patients frequently complain of nausea, belching, bloating, cough, or wheezing. Many factors have been identified that contribute to worsening of GERD symptoms, including increasing age, exercise after eating, smoking, a high-fat diet, and weight gain or obesity. Up to 50% of athletes complain of GERD symptoms during exercise, especially if they have had a previous history of GERD. Treatment of GERD begins with dietary and lifestyle modifications. It is recommended to avoid eating within 3 hours of lying down and to avoid large meals. Foods to avoid include caffeine, chocolate, mint, fatty foods, spicy foods, citrus fruits, and tomatoes. Other behavioral changes that may improve symptoms include discontinuing smoking, reduction of weight, and avoiding exercise for 3 hours after eating. Patients who fail to respond to these changes may require additional treatment with medications. Symptoms that persist despite treatment, especially in older adults, require additional evaluation and testing.

Trauma

Athletes who participate in sports, especially contact sports, are at risk for traumatic abdominal injuries. The muscles of the abdominal wall are vulnerable to strains or contusions. Hollow organs, such as the colon, intestine, or stomach, may suffer contusion or laceration. Solid organs of the abdomen, such as the liver and spleen, are more vulnerable to injury than hollow organs. The spleen, with its rigid capsule and vulnerable location, is susceptible to injury from a direct blow or possibly from an overlying rib fracture. Bleeding from an injured spleen is typically rapid, requiring immediate stabilization and transport to the hospital. Patients with infectious mononucleosis are at particular risk for spleen injury. *Splenomegaly* (enlarged spleen) occurs in about 50% of patients with mononucleosis, and the greatest risk of rupture is during the first 3 to 4 weeks of the infection. Normal impact from contact sports can result in a rupture in the mononucleosis-infected spleen. Spleen ruptures have been noted in the mononucleosis patient during normal physical activity without trauma.

Liver Injuries/Disorders

The liver is the largest solid abdominal organ and plays an essential role in the body's physiology. Severe liver injuries are fortunately rare in athletics but occur more frequently in high-impact sports such as football, wrestling, rugby, and soccer. Blunt liver injuries are less likely to cause severe bleeding; however, contusions and hematomas do develop. Complete evaluation and careful monitoring are necessary before return to sports is permitted.

Liver function tests may be elevated in the asymptomatic athlete, which is thought to result from the decreased blood flow during vigorous exercise. In most instances, these abnormal liver function readings are transient and benign, with return to normal conditions after rest and repeat testing. Persistent liver function elevation requires further evaluation for infections such as hepatitis, cytomegalovirus, or Epstein-Barr virus. Hepatitis A can be easily transmitted among athletes in close contact via the fecal-oral route or possibly through exposure to contaminated food or water, especially during travel. Hepatitis B or C infections are transmitted from blood to blood or via sexual contact. Education regarding proper hygiene, with good hand washing and protected sexual contact, as well as immunization for hepatitis A and B are recommended preventative measures.

"Side Stitch": Abdominal Pain

Athletes frequently experience a sharp side pain with exercise, commonly called a "side stitch." It occurs most often in runners and in those who are deconditioned and starting an exercise program. Activity after eating also seems to be an aggravating factor. The exact etiology is not known, but it is thought to result from a spasm in the diaphragm due to poor oxygen delivery to the diaphragm muscle. Symptoms seem to subside as training continues and conditioning improves. Persistent symptoms may require additional evaluation for other gastrointestinal causes.

Ellen Geminiani

See also Travel Medicine and the International Athlete

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Gender and Age Differences in Response to Training

Fitness training, or athletic training, can be defined as a systematic way of improving one's fitness for a desired benefit (e.g., one's health, one's sports performance). Training is typically conducted in two arenas—aerobic fitness and muscle strength and endurance—and operates around several different principles, including the overload-fatigue-recovery-adaptation cycle, reversibility, and specificity. It is important to note, however, that not everyone will have the same response to fitness training. Training response can be affected by one's general health (i.e., current physical fitness and ability levels, psychological readiness to participate, and nutrition status), age, and gender. This entry discusses gender and age differences in response to training.

Training in Children and Adolescents

The unique training needs and responses of children and adolescents center on several key areas, including their physical readiness and abilities, their psychological readiness to participate, their nutritional status and needs, and their injury patterns.

Children's physical state both affects and is affected by their training. Before children can participate in an athletic activity, they must have not only reached the appropriate developmental milestones that will give them the necessary gross and fine motor skills to participate but also attained a certain level of performance for the particular activity. Growth attenuation has been observed in children participating at certain levels of training intensity (e.g., gymnastics). Catch-up growth does occur when the intensity is returned to a more physiologic level. Exercise can also increase a child's bone formation during periods of rapid bone development. When performed under adult supervision, strength training can increase a child's neuromuscular activation, improving contractility as well as facilitating a balance between the agonist and antagonist muscle groups. Overtraining—for example, participating in one sport year-round—can result in overuse injuries, including growth plate injuries (e.g., Little League shoulder) and apophysitis. Return-to-play decisions should be conducted with predetermined, and strictly enforced, guidelines so as to avoid further or additional injury. Injury rates can also be reduced by providing appropriate coach and trainer education; rule, field, and equipment adjustments; and supervision.

Psychology is also an important component of pediatric and adolescent training. Before a child can participate in sporting activities, he or she must be psychologically ready. Preschool children are only ready to participate in activities that display and promote their general skills (e.g., kicking, running, and throwing) and are not quite ready to participate in a sporting event (e.g., baseball, soccer), as they are able to appreciate neither the rules of the game nor the theory of teamwork as grade school children are able to do. Middle school–age children have advanced capacities for teamwork, an increased understanding of competition, and improved skills for play. Pubertal adolescents' skills are further increased, as is their self-evaluation and ability to compare themselves with others in their sport.

Just as the readiness of the child affects his or her training and sport, so does his or her participation in athletics affect his or her psyche. Healthy participation can provide the motivation to continue the activity, confidence in oneself and one's abilities, and general enjoyment. Children and adolescents who participate in athletic activities also display a higher level of social function than their nonathletic peers. One caveat involves children and adolescents who overtrain. These individuals are susceptible to burnout, resulting in depression, fatigue, substance abuse, and eating disorders.

Balanced nutrition and good hydration are essential for good health and athletic participation. Boys and girls have the same energy needs until puberty, after which active males require more calories than active females. Energy needs are also affected by one's general health (e.g., age, height, weight, body composition, and stage of growth), as well as by the frequency, intensity, time, and type of activities performed. Lack of appropriate nutrition can affect not only one's health but also one's training and sports participation.

What would be the optimal training program for children and adolescents? Running is considered a safe and effective aerobic activity for children of all ages. Prepubertal athletes should use free weights and/or resistance bands, as the weight machines used by adolescents and adults are not configured to support younger children's needs. Strength training should be conducted at a low, but gradually increasing, resistance. In addition, power lifting should be reserved for those with closed growth plates. Whatever the program, it should be conducted to conform with the development and skills of the child or adolescent.

Training in Older Adults

On the other end of the spectrum are older adults who participate in training and athletics. Their ability to train effectively and their response to training affect each other. Older individuals typically have lower levels of spontaneous activity, resulting in decreasing athletic performance over time. In addition, older adults might continue to suffer from lingering past injuries, which may hinder their performance. Decreasing hormone levels result in a decreased training response, as well as in an increased training response time. Older individuals may also need increased time for recovery between bouts of activity. The physiologic parameters of older adults can be improved with training. Decreasing muscle function (due to negative alterations in motor unit functioning and enervation), increasing tendon laxity with decreased efficiency of muscle action, and decreasing lean body mass may all be attenuated with resistance training. Aerobic training can help improve the natural decrease in one's $\dot{V}O_2max$ (volume of maximum oxygen, a measure of cardiorespiratory fitness and the functional capacity of the heart). Fitness training has also been shown to decrease older adults' morbidity and mortality when compared with their sedentary peers.

An ideal program for older adults would consider their current health status and their current fitness level. Most exercise and training parameters would be similar to those recommended for young, healthy adults (30 minutes of moderate exercise five times a week and resistance training with 8 to 10 exercises, two times a week). Due to the increased recovery time needed by older adults, the frequency of activities may need to be decreased. Cross-training programs would allow for this recovery while also providing aerobic and muscle strength and endurance training.

Training in Women

The female response to athletic training is similar to that in males. With the same level of training, women can increase their cardiovascular fitness at the same rate as men. In addition, with resistance training, women see similar—if not greater—increases in strength (per body mass) than men; however, they will never reach the same absolute strength as men, due to their lower testosterone levels and the resultant decreased muscle fiber size and reactivity. Active women also have decreased percent body fat when compared with age-matched controls; however, due to their physiologic needs and hormone levels, they will never attain the low percent body fat levels of active men.

A unique female response to training involves the female athlete triad, which includes disordered eating, altered menstruation, and decreased bone density. Disordered eating, unintentional or intentional, can reach varying levels of severity, from low energy availability to anorexia and bulimia. Altered menstruation includes primary and secondary amenorrhea (absence of menstruation), as well as oligomenorrhea (decreased menstrual frequency) and anovulation. Decreased bone density, diagnosed by DEXA (dual-energy X-ray absorptiometry), can present with stress fractures. Girls and women involved in aesthetic and weight category sports are particularly susceptible to this triad.

A unique female training situation is the pregnant athlete, who is both helped and hampered by the many physiologic changes of pregnancy.

Increased cardiac output and cardiac reserve can actually boost exercise tolerance early in pregnancy. Exercise can also help increase her cardiac reserve and avoid hypovolemia (low blood volume), decrease labor time and complications, decrease the need for partum medications, and decrease her return time to activities postpartum. Some caveats to exercise during pregnancy include the increased risk of hypoglycemia (due to fetal use of glucose and increased maternal insulin levels) and the increased risk of sprains (due to increased ligamentous laxity). Any negative effects on fetal health in an uncomplicated pregnancy have not been observed.

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See also Exercise Prescription; Exercise Programs; Mental Health Benefits of Sports and Exercise; Physiological Effects of Exercise on Cardiopulmonary System; Risk Factors for Sports Injuries; Strength Training for the Female Athlete; Strength Training for the Young Athlete

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Genitourinary Injuries

Genitourinary injuries in sports are relatively uncommon. Injuries, when they do occur, can affect the external genitalia and the internal urinary system.

Anatomy

The kidneys are located behind the 12th rib in the retroperitoneum (the region behind the abdominal cavity). The *ureters* are tubes that begin at the kidneys and carry urine to the bladder. They run along the back of the abdominal cavity and cross the bony edge of the pelvis to attach to the bladder. The bladder, a hollow organ, is located in the pelvis, but it is at risk for injury when it is full. The urethra empties the bladder.

The female reproductive system is situated in the pelvis, except for the external genitals. Internally, the ovaries are connected to the uterus by the fallopian tubes. The vagina extends from the vulva (external genitals) to the uterus.

The male reproductive system is more vulnerable than the female. The penis, urethra, scrotum, and testes are located externally. The internal urethra and prostate are located inside the pelvis.

Renal Physiology

At rest, renal (kidney) blood flow is 20% of the cardiac output. The renal blood flow decreases with activity, with as much as 75% of its capacity at rest. The blood is filtered by the kidney structures called *glomeruli,* which act to prevent loss of protein and blood cells in the urine.

The kidneys help regulate the body's electrolyte and fluid balance. Antidiuretic hormone causes more water to be reabsorbed by the kidneys. It is stimulated by low blood volume, as when the body is in a state of dehydration.

Hematuria

Hematuria, or blood in the urine, is gross (seen by the naked eye) or microscopic (seen only under a microscope and identified with a urine dipstick or urinalysis). It occurs in about 75% of athletes who participate in sports. Hematuria can be caused by serious illness and by trauma to the kidneys and bladder. However, there is also an atraumatic cause called *athletic pseudonephritis*, or *exercise-induced hematuria.*

In athletic pseudonephritis, the decreased blood flow to the kidneys causes increased permeability of the glomerulus, allowing red blood cells to pass into the urine. This is a diagnosis of exclusion, meaning that it is important to rule out traumatic etiology and other medical problems that may cause hematuria, such as kidney stones, infection, tumors, and glomerulonephritis. Athletic pseudonephritis should resolve within 48 to 72 hours.

Athletes with hematuria who have symptoms, such as fever, or other findings on physical examination, including elevated blood pressure, are at high risk and need a more aggressive evaluation.

Athletes over 40 years of age are also at high risk. Low-risk athletes with hematuria should stop exercise completely for 24 to 48 hours and also repeat urinalysis. If the hematuria resolves, it is exercise induced, and they should be given reassurance. If the hematuria persists, they should undergo a more extensive workup with their physician or a nephrologist (a kidney doctor).

Proteinuria

About 70% of athletes have *proteinuria* (elevated protein levels in the urine) after activity. This is found on urinalysis. Unlike hematuria, there is a direct relationship between intensity of exercise and level of proteinuria. Proteinuria will begin within 30 minutes of exercise and clears in 24 to 48 hours.

Proteinuria may be exercise induced, but it may also be related to more serious illnesses (diabetes, glomerulonephritis, nephritic syndrome, etc.). As for hematuria, a complete history and a complete physical exam to identify any concerning signs or symptoms should be taken. If the history and physical exam are normal, the athlete should be counseled to stop activities for 24 to 48 hours and have a repeat urinalysis. If it remains positive, further workup must be considered to rule out more serious disease. If the test is negative, it can be exercise-induced proteinuria.

Urinary Tract Trauma

Renal Trauma

This is the most common genitourinary trauma and is covered more extensively in the renal injury section.

Ureter Trauma

This is unusual in sports and is usually associated with severe renal trauma, pelvic fractures, and lumbar spine fractures. The only treatment is surgical repair.

Bladder Trauma

Usually the bladder is well protected in the pelvis. However, a full bladder extends over the pelvis and is at risk for injury. Athletes will have a history of trauma and pain just above the genitals (suprapubic region). There will be hematuria and pain with urination (dysuria). Contusions can be treated with catheter placement, pain medication, and antibiotics for about 7 to 10 days. A bladder rupture is rare in sports and is associated with a pelvic fracture. This requires emergency surgery.

Reproductive System Trauma

Testicle Injuries

Direct trauma to the testicles may result in pain, nausea, anxiety, bruising, and swelling. All painful and swollen testicles need further evaluation with ultrasound. Ultrasound can help identify testicular rupture or fracture, as well as testicular torsion. If the ultrasound is normal, testicular contusions are treated with pain medications, rest, ice, and elevation of the scrotum.

Testicular torsion is a surgical emergency and must be suspected in any patient with scrotal pain and swelling. This is a twisting injury to the spermatic cord above each testicle. The twisting cuts off the blood supply, causing pain, and it may result in loss of the testicle. On physical exam, a darkening of the scrotum with swelling and a high-riding testicle may be visible; the affected side appears much higher than the other testicle. The elevation of the scrotum on physical exam will increase pain with testicular torsion.

Penis Injuries

The penis can be damaged by direct trauma, particularly if erect. This will cause painful swelling and bruising, and it is a surgical emergency. The penis may also be damaged by frostbite in cold-weather sports.

More commonly, cycling can irritate the pudendal nerve. This nerve can be compressed by riding in the saddle. It may cause increased pain in the penis and possibly priapism (or intractable erection).

Female Genital Injuries

The female reproductive organs are generally quite well protected inside the pelvis. The vulva (external genitalia) may be damaged by direct trauma. This can cause a hematoma (blood collection), which can be very painful. Since the vulva is very vascular, the hematoma may become quite large and may require surgical drainage. Women who fall while water-skiing may sustain a water douche, which is an injury where water is forced into the vagina. This can cause a laceration in the vagina and potentially severe internal bleeding and uterus damage.

Stress Incontinence

This is the involuntary loss of urine during exercise. It is quite common in women (about 30% to 50% of all regularly exercising women), especially after childbirth. This may be due to the shorter urethra and loss of muscular control after delivering an infant. Exercises such as running and jumping are likely to create incontinence. Treatment involves strengthening the pelvic floor muscles and using biofeedback. If that is not beneficial, there are medications (alpha agonists) that may be useful. Surgical intervention is indicated only if exercises and medication fail.

Special Populations

Wheelchair Athletes

Many wheelchair athletes do not have good neurologic control of their urinary tract. These athletes are at higher risk for infections and kidney stones. These injuries can be recurrent, and they can lead to permanent kidney damage. However, wheelchair athletes have a lower risk for these problems than sedentary wheelchair users.

Single-Organ Athletes

There is no clear evidence regarding clearance for athletes with a single kidney, testicle, or ovary. Single-organ concerns are discussed in other entries in this encyclopedia.

Kevin D. Walter

See also Kidney, Absence of One; Organ Injuries; Pelvic Fracture; Testicle, Undescended or Solitary

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Glenoid Labrum Tear

The shoulder has the widest range of motion of the joints in the body. The soft tissue (labrum) surrounding the glenoid cavity of the scapula helps stabilize the head of the humerus within the glenohumeral joint. Injury to the labrum can occur from overuse or as the result of trauma, such as a glenohumeral joint dislocation.

The physical examination of a labral tear involves a complete examination of the shoulder to test the condition of the surrounding muscles, capsule, and ligaments. Magnetic resonance arthrography is an effective way of visualizing a tear of the labrum.

Although small labral tears can be treated nonsurgically, factors such as the athlete's age or activity level may influence the decision to have a labral tear repaired surgically after a first-time dislocation.

Anatomy

The glenohumeral joint is made up of a ball-like humeral head rotating on a shallow dishlike surface, the glenoid. The bony anatomy of the glenohumeral joint is what allows the shoulder its wide range of motion. Because of this wide range of motion, the shoulder is very dependent on soft tissue restraints for stability.

The soft tissue restraints of the shoulder include the glenoid labrum, the surrounding capsule and ligamentous structures, and the rotator cuff musculature.

The glenoid labrum is a border of soft tissue that surrounds the bone of the glenoid and effectively deepens the glenohumeral articulation. The labrum may provide stability against humeral head translation.

The capsule extends from the periphery of the glenoid to the periphery of the articular cartilage of the humeral head. The capsule is thickened in three distinct areas. These thickenings make up the glenohumeral ligaments. The ligaments function to stabilize the shoulder by becoming taut in different positions of shoulder motion.

Increased reliance is placed on the surrounding rotator cuff musculature to maintain proper shoulder mechanics after injury to the labral tissue.

Shearing of the labrum from the anterior inferior glenoid was described by Bankart in 1923 and subsequently was named the *Bankart lesion*. Since that time, others have described avulsions of the labrum from other portions of the glenoid. These include SLAP (superior labrum anterior posterior) tears, ALPSA (anterior labral periosteal sleeve avulsion) lesions, and reverse and bony Bankart lesions.

A *SLAP lesion* refers to a tear of the superior portion of the glenoid labrum, extending from the anterior to the posterior glenoid.

A *bony Bankart* occurs when a shoulder dislocates and the impact of the humeral head on the glenoid breaks a piece of bone off the anterior inferior glenoid. A small piece of bone can often be reattached along with the soft tissue. Any piece larger than 25% of the glenoid needs to be repaired, fixed in place with a screw or heavy suture to prevent recurrent dislocation or subluxation.

A *Hill-Sachs lesion* is a bone bruise or bony defect that is often found in association with a Bankart lesion. When the humeral head is traumatically dislocated from the glenohumeral joint, the posterior superior aspect of the humeral head can strike against the anterior inferior glenoid and bruise or create a bony defect in the humeral head. Although these create an interesting pathology that can be explained by the mechanics of the dislocation, most do not need to be addressed surgically unless they engage the glenoid with shoulder rotation and contribute to shoulder instability. Lesions that involve greater than 30% of the humeral head or are associated with a capsular lesion are at a greater risk of leading to shoulder instability.

An *ALPSA lesion* refers to a tear of the anterior inferior glenoid labrum, where the periosteum remains intact (the periosteum is torn in a Bankart lesion). The intact periosteum pulls the labrum medially on the scapular neck. Untreated periosteal sleeve avulsions may cause the avulsed labrum to heal in an abnormal position, leading to chronic shoulder instability.

A *GLAD lesion* (glenolabral articular disruption) is a superficial tear of the glenoid labrum in combination with injury to the articular cartilage of the anterior inferior glenoid. Because the labrum remains firmly attached to the glenoid, GLAD lesions are not commonly associated with shoulder instability and can usually be treated conservatively (unless associated with a large cartilage defect or loose body).

Symptoms

An athlete who presents with a tear of the glenoid labrum will often complain of positional arm pain or pain that worsens with activities. Other symptoms include restricted range of motion, instability, and/or a catching sensation with shoulder motion.

Shoulder pain often correlates with the location of the labral tear (i.e., posterior shoulder pain with posterior labral lesions). Symptoms are often associated with activities. Patients may complain of a catching sensation, instability, or numbness and a tingling of the affected extremity. Nocturnal pain is variable.

Diagnosis

Physical Examination

Both shoulders should be made visible for the physical exam. This will allow the examiner to compare the symmetry of the injured shoulder with the opposite uninjured shoulder. Muscle bulk and scapular position can also be compared.

A sensory and motor exam should be performed to rule out any nerve injuries that may be contributing to muscle atrophy or a neuropraxia that may have occurred if the labral tear was associated with a shoulder dislocation.

Range of motion is assessed in forward flexion, extension, abduction, and internal and external rotation with the elbow at the side and at 90° of abduction. Internal rotation at the side is measured by having the patient reach up to his or her back as far as possible and recording the level of the most superior vertebral body that he or she is able to reach (Apley scratch test). Any associated pain, catching, subluxation, or apprehension of dislocation with range of motion should be documented.

Rotator cuff strength should also be evaluated. Supraspinatus strength is tested with The Jobe empty can test. This is performed by placing the arm in 90° of abduction and 30° anterior to the coronal plane with the arm internally rotated so that the thumbs are pointing toward the ground. The patient is then asked to resist a downward directed force by the examiner.

The subscapularis muscle can be tested with either the lift-off test or the belly press test. The lift-off test is performed by having patients place the back of their hand on their back and then lifting the hand away from the back. When performing the belly press test, patients place the palm of their hand on their abdomen with the elbow brought anteriorly until it is in line with the hand. Patients are then asked to resist the examiner's attempt to lift their hand off their abdomen. A positive test occurs when a patient drops his or her elbow posteriorly in an attempt to supplement a weak subscapularis muscle by assisting with the posterior deltoid.

The external rotators (infraspinatus and teres minor) are tested with the elbow at the side while the examiner resists attempted external rotation.

Tests specific to evaluate a torn glenoid labrum include the Speed test, the O'Brien test, the anterior apprehension test, the relocation and release tests, the load and shift test, and the jerk test.

The Speed test evaluates the strength of the biceps and the integrity of its attachment. It is performed with the shoulder flexed forward 90° with the arm abducted approximately 30° from the sagittal plane. With the hand supinated, the patient resists the examiner's inferiorly directed force. Resulting shoulder pain is indicative of injury to the biceps tendon attachment at the superior glenoid labrum.

The O'Brien test evaluates the integrity of the glenoid labrum. This is performed by flexing the shoulder to 90°, pronating the arm so that the thumb is pointing toward the ground, and adducting the arm approximately 15° from the sagittal plane. The O'Brien test is positive if there is shoulder pain with a resisted downward force on the arm in this position and if the Speed test is negative.

The anterior apprehension test is the classic provocative test for anterior instability. It is performed by placing the arm in 90° abduction, extension, and external rotation with the elbow flexed to 90°. The examiner then progressively externally rotates the shoulder. A patient with anterior instability will complain of pain in the anterior shoulder or apprehension of impending dislocation.

The relocation test increases the specificity of the anterior apprehension test for cases of subtle instability. It is performed by placing the shoulder in a position of apprehension and then applying a posteriorly directed force over the humeral head. The posteriorly directed force decreases the patient's pain and reduces the apprehension of impending subluxation. When the examiner removes the posterior force, the pain and apprehension return (a release test).

Anterior and posterior labral pathology can also be tested with the load and shift test. This test is performed with the patient lying supine on the examination table. The table serves to stabilize the scapula. The patient's arm is slightly abducted from his or her side. The examiner then stabilizes the patient's shoulder with one hand and grasps the proximal humeral shaft with the other hand. While slightly compressing the humeral head against the glenoid, the examiner attempts to slide the proximal humerus off the anterior and then the posterior glenoid rim. In the stable shoulder, anterior or posterior translation of approximately half the distance of the humeral head will occur.

The jerk test is an additional test for posterior shoulder instability or a posterior labral tear. It is performed by placing the patient's arm in 90° of flexion, adduction, and internal rotation with the elbow flexed to 90°. The examiner then applies a posteriorly directed force at the elbow, attempting to push the humeral head posteriorly off the glenoid. A jerk or clunk is felt as the humerus slips over the edge of the posterior glenoid rim.

Imaging

Imaging of a patient with a suspected labral tear should begin with plain radiographs, including anteroposterior (AP), scapular Y, and axillary views, to rule out any bony pathology. Additional views that may be helpful to evaluate for bony injury include the West Point and Stryker notch views. The West Point view puts the anterior inferior glenoid rim in a better position to detect rim fractures (bony Bankart). The Stryker notch view evaluates the humeral head for an impaction (Hill-Sachs) lesion. The glenoid labrum itself is best visualized with an MRI or MR arthrogram of the shoulder.

An MRI of the shoulder usually includes coronal, axial, and sagittal views. A labral tear is best visualized in the axial plane. In this view, the torn labrum is seen as soft tissue elevated off the surface of the glenoid. When dye has been injected into the shoulder prior to the MRI (MR arthrogram), the dye is seen to extravasate between the soft tissue and the bone, making the tear easier to visualize.

Recent comparisons quantify the sensitivity of an MRI alone in diagnosing a labral tear to be 91% to 93%. The addition of dye in the glenohumeral joint (MR arthrogram) improves the sensitivity of diagnosing a labral tear to 96%.

Treatment

Nonsurgical

Small labral tears that are not associated with instability can sometimes be treated with an initial period of anti-inflammatories and rest, followed by a program of physical therapy, to strengthen the surrounding rotator cuff musculature and the periscapular stabilizers.

Some of the factors that come into consideration in determining whether a labral tear should be fixed surgically or not include the size of the labral tear, the degree of shoulder instability, the age of the patient at the time of dislocation, and whether the athlete participates in contact or collision sports.

Traumatic dislocations that occur in patients who are less than 20 years of age are at a significant risk for redislocation. A youth or adolescent with a first-time dislocation is at a 70% to 100% risk of redislocation.

Risks associated with recurrent dislocation include damaging the articular cartilage and a longer time out of sports (an unsuccessful nonoperative period followed by postoperative treatment and recovery).

Surgical Treatment

Arthroscopy

Some of the benefits of treating a labral tear arthroscopically include reducing the morbidity associated with a large incision and releasing of the subcapularis muscle from its attachment site on the proximal humerus, as required in an open-surgical approach.

Arthroscopy is additionally beneficial because it allows the physician to visualize and probe the entire glenoid labrum for any areas of detachment.

Shoulder arthroscopy is performed through two to three small incisions made around the shoulder joint. These incisions are used for placement of the camera and the instruments used to evaluate and repair the torn labrum. With the camera in the shoulder, the entire glenoid labrum can be seen and evaluated. Other structures that can be visualized include the articular surfaces of the glenoid and the humeral head, the long head of the biceps, the rotator cuff attachments, and the capsule.

A labral tear is repaired by suturing the detached labrum back to the glenoid with suture anchors. Suture anchors are made up of a bioabsorbable or metal anchor that is placed into the bone of the glenoid. The anchor has attached sutures, which are then used to secure the torn labral back to the bone of the glenoid while it heals.

Open Treatment of Shoulder Instability

An open procedure is performed by making a longitudinal incision in the axillary crease. Dissection is carried down through the subcutaneous level to an interval between the pectoralis major and the deltoid muscles. The subcapularis muscle is then identified and released from its attachment on the proximal humerus. The capsule can then be split and the labral tear identified and repaired. The repair can either be performed using suture anchors, similar to an arthroscopic repair, or by suturing the torn labrum back to the glenoid through small drill holes placed in the edge of the glenoid.

After Surgery

The shoulder is usually protected in a sling for 4 to 6 weeks after surgical repair of the glenoid labrum. The sling should be removed several times a day for elbow and wrist range-of-motion exercises.

During the first 2 weeks after surgery, patients may be allowed to perform pendulum-type exercises with their arm hanging independently at their side while they gently swing their arm in small circles.

Formal physical therapy begins at the 2-week postoperative visit. Initially, forward flexion to 90° is allowed. External rotation is limited to neutral for the first 6 weeks. At 6 weeks, the patient is allowed to increase external rotation to 30°. Full external rotation range of motion is allowed at 4 months postoperatively. Progressive strengthening exercises are begun at 6 weeks postoperatively. Return to sports is anticipated to occur approximately 4 months after surgery

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See also Musculoskeletal Tests, Shoulder; Shoulder Injuries; Shoulder Injuries, Surgery for

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Gluteal Strain

Gluteal strain is a trauma to the gluteal muscles, a group of three muscles of the buttocks and upper thigh, the gluteus maximus, gluteus medius, and gluteus minimus. A strained muscle is colloquially known as a *pulled muscle* and involves a tear of the muscle fibers. The tear occurs as a result of overstretching the muscle beyond the amount of tension or stress that it can withstand. The problem can also result from using the gluteal muscles too much on a particular day or due to a blow to them. Suddenly putting stress on the muscles when they are not ready for it also predisposes them to a tear.

Sports activities include complex and coordinated processes that involve the entire body. Sports that require bursts of speed increase the chances of getting a gluteal strain. Especially sports such as running, hurdles, long jump, basketball, soccer, football, rugby, and so on put the players at risk of having a gluteal strain. These are dynamic sports and require explosive movements such as sprinting, jumping, shooting, and so on, with large forces generated by muscles and tendons.

In many running overuse injuries, the upper buttock muscle (gluteus medius) is the culprit. This is because during running the body is always either completely in the air or dynamically balanced on one leg. And in both situations, the gluteus medius is the key muscle. Situated on the upper edge of the hip, the gluteus medius is responsible for lifting the leg away from the body, helping it rotate inward and outward, and essentially keeping the pelvis stable, so that the pelvis doesn't tilt heavily toward the ground.

Symptoms

Pain and tenderness in the buttocks and stiffness and weakness of the gluteal muscles are indicative of a gluteal strain. Bruising also appears around the gluteal muscles.

During physical activity, 70% of the cardiac output is diverted to muscle blood flow. So any injury is likely to lead to significant bruising, which may be intramuscular (i.e., within the muscle sheath) or intermuscular. Intramuscular hematoma is a more serious injury, and the resultant swelling usually persists beyond 48 hours and is accompanied by significant tenderness, pain, and impaired muscle function. Intermuscular hematoma, on the other hand, causes dispersal of blood within the fascial planes, and after an initial period of increased pressure, there is a relatively rapid reduction in pressure and swelling and return to normal muscle function.

Diagnosis

Tenderness and bruising on the buttocks and pain on contracting the gluteal muscles, particularly against resistance, are diagnostic of a gluteal strain. For severe gluteal strains, magnetic resonance imaging (MRI) is used to see the extent of injury and to predict the length of the recovery period. Depending on their degree of severity, the strains could be graded as follows:

Grade I: This is a mild strain with microtearing of fibers. Less than 5% of muscle fibers are involved. This requires 2 to 3 weeks to heal.

Grade II: There is more extensive damage to the gluteal muscle with more fibers involved, but the muscle is not completely ruptured. The rest period required is usually between 3 and 6 weeks.

Grade III: This involves complete rupture of the muscle, but it is rare in gluteal muscles. It is surgically repaired; exploration and apposition of the muscle ends are required. It takes 3 months of rest to heal.

Gluteal strains should be rested and allowed to heal. If the patient continues to play, the condition will worsen. If ignored, a Grade I strain has the potential to become a Grade II strain or even a complete rupture.

Treatment

The treatment should aim to stop the bleeding within the tissue as soon as possible, in order to allow the fibrin scaffold to develop on the damaged capillaries.

The immediate treatment consists of the RICE protocol: *r*est, *i*ce, *c*ompression, and *e*levation.

Rest: Stop all activities that cause pain to avoid the strain becoming more serious. The injured player may be able to continue playing, but the importance of his or her contribution to the current match must be weighed against the increasing damage that is being done with every minute that the player continues in the game.

Ice: Apply ice or a cold pack to the affected buttock for 15 to 20 minutes, four times a day for several days after the injury. Wrap the ice or cold pack in a towel. To avoid freezing the skin, do not apply the ice directly to the skin. A cold bath is a popular treatment of gluteal strains as it offers two distinct improvements. First, it allows controlled and even constriction around all the muscles, effectively closing the microscopic damage and numbing the pain. Saint Andrew's cross-country coach John O'Connell, a 2:48 masters marathoner, recommends to hit the ice baths before the ibuprofen. "Pain relievers can disguise injury," he warns. "Ice baths treat both injury and soreness." The second advantage involves a physiological reaction. Assuming that one has overcome the mind's initial flight response, the body fights back by invoking a *blood rush*. This rapid circulation flushes the damage-inflicting waste from the system while the cold water outside preserves the contraction. The blood rush revitalizes the very areas that demand fresh nutrients.

Compression: Wrapping the gluteal region reduces swelling.

Elevation: The strained gluteal region should be kept close to the level of the heart to keep the blood from pooling into the injured area.

This immediate treatment is usually accompanied by the use of NSAIDs (nonsteroidal anti-inflammatory drugs), such as ibuprofen, which both reduce the immediate inflammation and serve as an analgesic.

The healing process of the gluteal muscles starts with the inflammatory response and consists of three stages. First, new muscle fibers grow from special cells within the muscle. Second, there is bleeding in the gap between the torn muscle ends, and from this blood, a matrix or scaffold is formed to anchor the two ends together. And third, the scar matures, and collagen becomes aligned along the lines of external stress.

Rehabilitation

When the acute pain in the gluteal muscles is gone, the patient should start gentle stretching but stay within pain limits and afterward begin strengthening exercises. Gluteal muscles can be stretched using the following two exercises:

Single knee-to-chest stretch: Lie on your back with your legs straight out in front of you. Bring one knee up to your chest, and grasp the back of your thigh. Pull your knee toward your chest, stretching your buttock muscle. Hold this position for 15 to 30 seconds, and return to the starting position. Repeat three times on each side.

Piriformis stretch: Lying on your back with both knees bent, rest the ankle of your injured leg over the knee of your uninjured leg. Grasp the thigh of your uninjured leg, and pull that knee toward your chest. You will feel a stretch along the buttocks and possibly along the outside of your hip on the injured side. Hold this for 15 to 30 seconds. Repeat three times.

The patient can begin strengthening his or her gluteal muscles as soon as the sharp pain is gone and there is only a dull ache when doing the gluteal isometrics.

Gluteal isometrics: Lie on your stomach with your legs stretched straight out behind you. Squeeze your buttock muscles together, and hold for 5 seconds. Release. Do 3 sets of 10.

After gluteal isometrics become easier, the patient can do the next gluteal-strengthening exercises.

Prone hip extension (*bent leg*)*:* Lie on your stomach with a pillow underneath your hips. Bend your injured knee, tighten up your buttocks muscles, and lift your leg off the floor about 6 inches (15.2 centimeters). Keep your knee straight. Hold for 5 seconds. Then, lower your leg and relax. Do 3 sets of 10.

Resisted hip extension: Stand facing a door with elastic tubing tied around the ankle on your injured side. Knot the other end of the tubing, and shut the knot in the door. Pull your leg straight back, keeping your knee straight. Make sure you do not lean forward. Do 3 sets of 10.

Hip abduction (with elastic tubing): Stand sideways near a doorway with your uninjured side closest to the door. Tie some elastic tubing around the ankle on your injured side. Knot the other end of the tubing, and close the knot in the door. Extend your leg out to the side, keeping your knee straight. Return to the starting position. Do 3 sets of 10.

After the gluteal-strengthening exercises become easy, the patient can strengthen the buttocks by doing lunges.

Lunges: Stand and take a large step forward with your right leg. Dip your left knee down toward the floor, and bend your right leg. Return to the starting position. Repeat the exercise, this time stepping forward with the left leg and dipping the leg on your right side down. Do 3 sets of 10 on each side.

Prevention

For reducing the chances of sustaining a gluteal strain, the player should undertake the following measures.

A warm-up prior to matches and training is thought to decrease gluteal muscle stretch injuries because the muscle is more extensible when the tissue temperature has been increased by 1° to 2°. A good warm-up should last about 20 minutes—starting gently and finishing as a full-pace activity. Recovery after training sessions and matches can be enhanced by performing a cooldown, which is thought to help muscles get rid of their waste products. This is the ideal time to do stretching exercises.

Maintaining good gluteal muscle strength and flexibility allows a player to carry out match activities in a controlled manner and decreases the uncoordinated movements that can lead to injury.

A diet that is high in carbohydrates taken 48 hours before the match can supply the body with adequate energy for muscle contraction. Otherwise, muscles become short of fuels, and fatigue sets in, predisposing a player to injury.

Farah Bano

See also Hip, Pelvis, and Groin Injuries; Musculoskeletal Tests, Hip; Strains, Muscle

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Golf, Injuries in

A sport enjoyed by people of all ages and fitness levels, golf is not known for traumatic injuries. However, many injuries can occur in the golfer, and these can be intrinsic or extrinsic. Intrinsic injuries occur based on the individual traits of the golfer. Variables such as the golf swing, skill level, age, gender, and athletic condition affect the injury patterns of golfers. Most of the intrinsic injuries in a golfer occur as a consequence of overuse of a part of the body. Extrinsic factors that can cause injury occur independently of the individual golfer. Variables such as clothing, environment, course terrain, and other golfers can be a source of injury.

Intrinsic Injuries

Most intrinsic golf injuries are the result of either of two mechanisms: (1) overuse during play or practice or (2) the golf swing mechanics. Certain injury patterns are more common in different subgroups. Discussions of these patterns of injuries are given below.

The Golf Swing

Before discussing the various patterns of injury of golfers, it is important to understand the golf swing. Understanding the mechanics of the golf swing is helpful in understanding the mechanisms of injury. The body coils from side to side using the golf club to swing through 360°, impacting the ball at about the 180° mark.

The golf swing can be divided into four phases:

1. *The back swing:* The dominant arm is maximally abducted and externally rotated; the nondominant arm crosses the body with a straight elbow. The core of the body is coiled away from the target. The weight is shifted onto the inner side of the dominant foot.
2. *The swing phase:* The body begins to uncoil. The head of the club is brought down to strike the ball. The nondominant arm is pulled toward the nondominant side, while the dominant arm guides the club to the position of impact. Weight is shifted from the dominant foot to the nondominant foot.
3. *The impact phase:* This is where the club hits the ball using the body's maximum uncoil velocity. Using iron clubs, the ground is struck slightly under the ball; when teeing off with the wood, the golf club hits the ball suspended by a tee.
4. *The follow-through:* This part of the golf swing occurs after impact, and the remainder of the circle is completed and held in position. The nondominant arm is abducted and externally rotated, and the dominant arm is adducted and flexed. The weight is on the nondominant foot. The pelvis is twisted toward the target.

Back Injuries

Most experts agree that among the most common injuries in golf are those to the back, especially lower back injuries, particularly among amateur male golfers. The back must coil in a twisting and side-bending motion. Inconsistencies of the swing mechanics can cause injury.

The vertebral motion of the back is important in the kinetic chain of the golf swing. The timing and tempo of a golf swing require the fluid motion of all the components of the back to move and to fire in sequence with the coordination. Disruptions in the fluidity of motion can cause injury. There are several areas within the back that can be injured. Often, there are several component areas involved in the same injury—namely, the muscles, joints, ligaments, and bones. The level of pain from an injury can vary.

Muscle Injuries

Misfiring of muscle sequences or overstretching a tight muscle can cause injury in the back. Weak stabilizing or postural muscles require other muscle groups to stabilize the back through the golf swing. This, in turn, predisposes the golfer to injury and decreases the swing power. Reduced swing power reduces the distance of the driven ball owing to inefficiencies of the muscle mechanics. Similarly, a deconditioned muscle fatigues more easily and is more prone to injury. When a muscle is injured, it often shortens; when this happens, the muscles may spasm. This can be very painful.

The voluntary and postural muscles of the back and oblique abdominal muscles require a sequential series of firing and relaxing. Recently, there has emerged a clearer understanding of the transverse abdominis muscle, which provides stabilizing forces to the spine through the golf swing. Strengthening of this muscle can increase the distance of a golfer's swing. The postural muscle most involved in the golf swing is the multifidus.

Spinal Joints

The joints of the spine can also be injured. Spinal motion in the lumbar and thoracic spine follows Fryett's laws: In brief, when a group of vertebrae is rotated to one direction, the same vertebrae side bend to the opposite direction. The golf swing requires the vertebrae to rotate quickly and therefore to side bend quickly. At times, if the rotation is not smooth, a single vertebra or group of vertebrae in motion can become restricted relative to the remainder of the spine. This is known as *somatic dysfunction* and can be treated with osteopathic manipulative treatments. Another joint problem seen in older golfers is osteoarthritis of the spine. The surfaces of the joints become less smooth with advancing arthritis, making the golfer more prone to injury and inflammation of the joints involved.

Ligamentous Back Injuries

These can occur when the bony structure is pushed beyond an anatomic barrier, and they may be seen in a golfer who has increased mobility at a vertebral segment or if the force on the impact phase results in sudden deceleration.

Bony Injuries

Bony injuries of the back occur far less frequently and are uncommon in the vertebrae. Compression fractures can occur in elderly golfers, although this is rare. Stress fractures of the ribs are more common but, overall, less common than the soft tissue injury described above.

Chest Wall Injuries

Chest wall injuries such as rib stress fractures are caused by muscles pulling on the ribs to stabilize the scapula during the golf swing. Muscle strains along the chest wall can also occur. Muscle strains of the chest wall are more common than stress fractures.

Rehabilitation

Rehabilitation of core muscle groups can increase the power of the golf swing as well as prevent injury. The stretching and strengthening of core muscle groups such as the multifidi, the transverse abdominous, and the oblique abdominal muscles play an important role in the prevention and treatment of low back pain in golfers.

Elbow Injuries

Elbow Tendon Injuries

These are another set of very common golf injuries. Female golfers tend to have more elbow injuries than their male counterparts. Medial epicondylitis ("golfer's elbow") and lateral epicondylitis ("tennis elbow") can result from overuse injury with repetitive swings of the golf club. Additionally, these tendon injuries can also occur from a sudden deceleration injury in the impact phase of the golf swing when the club divots in the ground or hits a surface that is immobile, such as a tree stump or a rock. The nondominant side is more prone to injury and more likely to have lateral epicondylar injuries.

Bone Injuries

These injuries, including avulsion fractures where the tendon is stronger than the bone and pulls a part of the bone off with forced contraction, are more common in young golfers. Young golfers, who are still growing, have a risk of injuring their open growth plates and suffering elbow pain; problems with elbow catching should be evaluated by a sports physician.

Rehabilitation and Prevention

Stretching the forearm and changing the grip strength and location can be helpful for prevention of injury. Using an elbow brace and resting the elbow as well as using ice and anti-inflammatory medications when appropriate are measures used to rehabilitate elbow tendon injuries.

Shoulder Injuries

Shoulder injuries are very common among golfers. Injuries to the shoulder are more frequent in professional golfers than in amateurs and are more common in the nondominant side. A high degree of motion is required from the backswing through the follow-through swing. Equal strength is needed in both shoulders for a successful swing. Injuries such as subacromial impingement can occur when the space between the humerus and clavicle is narrowed. When the nondominant arm crosses the body on the backswing, it can enclose this subacromial space and cause inflammation. Rotator cuff strain and acromioclavicular joint strain are overuse injuries seen in golfers. Instability of the shoulder joint can also happen in golfers and predispose the shoulders to other injuries. Pain in the back of the shoulder during the downswing could be a sign of tightness or injury in the rotator cuff. Dominant shoulder pain at the height of the back swing or as the golfer begins the downswing are signs of impingement. Pain in the front of the shoulder could mean an impinged rotator cuff or an acromioclavicular strain.

Rehabilitation and Prevention

The golf swing requires equal strength through both the upper extremities. A stretching and strengthening program that focuses on the latissimus dorsi and the rotator cuff can be helpful. Steroid injections and resting the shoulder can aid in the shoulder rehabilitation process.

Wrist and Hand Injuries

Wrist Tendon Injuries

These are common injuries in golf but chiefly in professional golfers. Through the golf swing, the wrist undergoes a complex series of movements. On impact, the wrist is held straight, and the muscles of the forearm and the tendons of the wrist are held in position, resisting the impact of the ball. As with other sports, overuse of the tendons through practice or playing can predispose them to injury. Ideally, the motions of the wrist in proper swing mechanics are hingelike, from the fifth finger toward the thumb. Amateurs can overgrip or undergrip the club, changing the dynamic of the golf swing and the force of the wrist on impact from the ball. In general, on the dominant hand, the tendons that are more prone to injury are the flexor carpi ulnaris and the extensor carpi ulnaris. These tendons are at the ulnar side of the wrist on the palmar and dorsal side, respectively. Flexor carpi radialis tendinitis can also occur on the dominant side in golfers who use more pronation in their wrist mechanics. This tendon is on the radial palmar side of the wrist and can be tender to the touch. The tendons most involved in injury of the nondominant wrist are the adductor pollicis brevis and the extensor pollicis tendons. When the sheath around these tendons becomes inflamed, it is known as *de Quervain tenosynovitis* or *paratenonitis*.

Bony Wrist Fractures

These are uncommon, but a hook of the hamate fracture can occur in all gripping sports. The golfer would describe a sudden and severe pain after the impact phase of the golf stroke. Pain is at the palmar and ulnar sides of the hand and gets worse when moving the wrist from side to side. These fractures have a high incidence of nonunion; therefore, if a hook of the hamate fracture is suspected, the golfer should seek medical attention without delay.

Hand Injuries

Trigger finger results from irritation of the tendon pulley, where the metacarpal bones connect to the phalanges. The golf club is grasped across the metacarpal bones, compressing the tendon, tendon sheath, and pulley area. The pulley area can get irritated and enlarged, causing the finger to get stuck in a flexed position.

Rehabilitation and Prevention

Wrist injuries in golf are related to grip tightness and the grip size of the golf clubs. Changing the grip width and tightness and minimizing the flexion and extension in the golf swing can help avoid wrist injuries. To prevent further hand and forearm injuries, the golfer should not grip the club as tightly. The golf glove worn on the nondominant hand can also help the golfer grip the club with less shearing force, preventing blisters and calluses. Wider grips could also be added for prevention. Having newer grips on the club can also prevent friction and hand, wrist, and forearm injures. A trigger finger can be injected with steroids to decrease inflammation.

Foot, Ankle, and Knee Injuries

Injuries to the foot, ankle, and knee are less frequent in golf. The dominant foot and the non-dominant foot have very different motions through the golf swing. Shoes that accommodate the side-to-side motion of the foot for the golf swing are not as comfortable for walking.

Plantar Fasciitis

This can occur in walking golfers. The plantar fascia is a thick tissue that spans the sole of the foot. If it gets irritated, it can inflame and cause pain. This condition is most painful on taking the first few steps after resting for a period of time.

Chronic Tendon Injuries

Crowding or shearing forces in the golf shoe over time can cause chronic tendon injuries to the toes and deformities such as hammer and claw toes.

Morton Neuroma

Irritation of the digital nerves, between the metatarsals, can cause Morton neuroma. This is more commonly seen between the third and fourth metatarsal heads. The golfer would experience a sensation of burning in the concerned toes. Chronic irritation of the nerve causes pain and leads to the formation of a fibrous tissue, called a *neuroma*, around the nerve.

Achilles Tendinitis

This condition is most common in middle-aged and older golfers. Irritation caused by a golf shoe on the heel of a golfer who has a tight Achilles tendon can cause it to become inflamed. The area most common is the point of attachment to the calcaneus. Chronic inflammation can cause rupture to this tendon if left untreated. Keeping the Achilles tendon stretched and seeking medical advice with persistent heel pain is important to prevent injury.

Ankle sprain can occur in golf in a twisting injury or fall and is more commonly related to the golf shoes or wet ground.

Knee injuries are less common in golfers and can be related to uneven surfaces.

Rehabilitation and Prevention

The golf shoe should be cleated to prevent falls, cushioned in the heel, and wide enough to allow for weight transfer. Socks should be cotton and should wick the sweat away from the skin. This prevents blisters and fungal infections such as athlete's foot.

Mind-Body Disconnection

Golf is a sport that requires a close mind-body connection. The golfer is mindful of all the areas of the body through the golf swing and the putt. In golf, there is a condition called "Yipes." It can occur during a putt and during shorter-distance swings. The golfer has involuntary movements of the arms when he tries to hit the ball. This is thought to be a mind-body disconnect and has debilitated professional golfers. In this condition, increasing the club length can sometimes help.

Extrinsic Injuries

Extrinsic injuries are injuries that are not inherent to the golfer or the individual's golf swing.

Head Injuries

These are more common in young and inexperienced golfers. The golfer can be hit with the club during a backswing or a practice swing. Head injuries also occur with flying stray balls. A golfer is supposed to yell the word *fore* when a ball is going to land near another golfer.

Sunburn

On an 18-hole course, a golfer could be in direct sunlight for 4 to 5 hours. It is recommended to limit sun exposure with sunblock, hats, and protective clothing. Excessive sun exposure can predispose the golfer to skin cancer.

Dehydration and Heat Injuries

The feeling of thirst occurs when a body's fluid reserve is less than 20%. The thirst drive can decrease in the senior golfer, making this population more prone to heat illnesses; however, these illnesses do affect all age-groups. Being on a golf course for 4 to 5 hours in the warmth, humidity, and sunlight, a golfer can get dehydrated. This can lead to more serious medical conditions—heat exhaustion and heat stroke. Heat exhaustion occurs when the body starts to deregulate its own body temperature. Fainting, exhaustion, dizziness, and a mild temperature increase are signs of heat exhaustion. In heat strokes, the body deregulates its internal heat control. The body can heat to up to 106 °F. The hallmark of a heat stroke is that the athlete stops sweating. This can lead to organ failure. These are serious medical conditions and require medical attention. It is important to cooldown the body by applying bags of ice and removing the golfer from direct sunlight.

Lightning Strike

Lightning is an important environmental hazard that deserves consideration in the game of golf. In 1975, professional golfer Lee Trevino was struck by lightning during a tournament, suffering a spinal injury that required surgery. Though these are not common golf injuries, they can be fatal or can cause severe organ damage. Golfers should seek shelter in the clubhouse during inclement weather.

Golf Cart Injuries

These are relatively uncommon, but the incidence is rising, especially among youthful golfers. Falling from the golf cart and being struck by a cart are common mechanisms of injuries.

Judy L. Brasier

See also Achilles Tendinitis; Back Injuries, Surgery for; Elbow and Forearm Injuries; Foot Injuries; Lower Back Injuries and Low Back Pain; Lower Back Muscle Strain and Ligament Sprain; Neck and Upper Back Injuries; Wrist Tendinopathy

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Groin Pain

Groin pain in the athlete is one of the most complex diagnostic challenges for sports medicine physicians. Due to the overlapping anatomy of this area, many different injury patterns can produce groin pain. Understanding the anatomy of the groin is the key to determining the pain source. Specific physical exam findings should alert the clinician to the possible diagnoses. Imaging techniques including X-rays, magnetic resonance imaging (MRI), and bone scans can be helpful in identifying or ruling out certain conditions. Physical therapy is a key component of most treatment regimens.

Anatomy

The complex anatomy of the groin area must be understood to properly diagnose the conditions that are causing pain in the athlete's groin. The hip joint is located directly in the groin area. The hip is a ball-and-socket joint made up of the head of the femur bone (ball) and the acetabulum (socket). The femoral head connects to the femoral neck, which then attaches to the shaft of the femur. The hip joint is lined with cartilages, which provides a smooth, low-friction surface to allow for free movement. Surrounding the acetabulum is a rubbery ring of cartilage that attaches to its outer rim, called the *acetabular labrum*. The labrum functions like an O-ring to help hold the femoral head in the socket of the acetabulum. The outer hip has tough strong ligaments that surround and reinforce the joint and prevent the femoral head from dislocating out of the acetabulum.

Problems intrinsic to the hip joint can cause groin pain in athletes. Some common causes include stress fractures of the femoral neck, impingement of the femoral head on the acetabulum, tears of the acetabular labrum, and cartilage injuries to the femoral head or acetabulum.

Surrounding the hip joint are many different muscles and tendons that control movement of the abdomen, hip, and leg. A tendon is a taut, thin, ropelike portion of a muscle that attaches to a bone. The psoas muscle is responsible for hip flexion (bending the hip upward toward the chest). The psoas muscle tendon lies directly in front of the hip joint and attaches to the shaft of the femur. The adductor muscles are responsible for hip adduction (moving the hip toward the opposite hip). These muscles run just below the groin on the upper, inner portion of the thigh. The adductor muscles become tendons that attach to the lower portion of the pubic bone, above the genitalia. The rectus abdominus is the major abdominal muscle. It also attaches to the upper portion of the pubic bone. A bursa is a fluid-filled sac that lies between the tendons and the bone to allow the tendons to slide without much friction. There is a large bursa where the psoas muscle tendon lies over the acetabulum and another bursa near the adductor tendons and the pubic bone.

Problems with the muscles, tendons, and bursas can cause groin pain in the athlete. Muscle injuries include sprains, strains, and tears. Tendons and bursas can become irritated and inflamed, leading to tendinitis or bursitis. Avulsion injuries occur when a strong muscle contraction causes a tendon to pull off a small piece of bone where it attaches. Imbalances of muscle forces may be responsible for osteitis pubis and sports hernia.

History

A detailed history should be obtained from the athlete with groin pain. How long has the pain been going on? Was there an actual injury? Is the pain constant or episodic? Which specific activities exacerbate the pain? Does the groin hurt with weight bearing? Is the pain nearer to the groin or to the pubic area? Groin pain following a traumatic injury suggests a hip labral tear, a cartilage injury, an avulsion fracture, or a muscle strain. A slow-onset pain near the pubis may be caused by osteitis pubis or sports hernia. Groin pain with weight bearing that develops over time might represent a femoral neck stress fracture. Certain sports produce characteristic injury patterns. Dancers who constantly strain the motion limitations of their hip joints have a higher incidence of psoas tendinitis, snapping hip, labral tears, and hip impingement. Osteitis pubis, adductor strains, and sports hernia are common in kicking sports such as soccer and rugby. Female long-distance runners have a high incidence of stress fractures of the femoral neck.

Physical Examination

The physical exam attempts to differentiate between muscle/tendon/bursa pain, pubic pain, and hip joint pain. Initially, the muscles, tendons, and bursas near the groin are individually examined for tightness or point tenderness. Comparison with the other hip may be necessary to determine if a particular muscle is tight. The pubic bone and groin are separately palpated, looking for tender areas. The hip joint is then provocatively stressed to see what movements cause pain. The hip impingement test is done by having the athlete lie on his or her back while the examiner flexes and internally rotates the hip (bends the hip and knee up toward the chest while rotating the foot away from the body). This maneuver causes the hip joint to compress, and if pain is produced, it is likely that the hip joint is the source of pain.

Imaging

X-rays of the hip and pelvis can show changes consistent with hip impingement and bony avulsion fractures. Stress fractures of the femoral neck may or may not be visible on X-rays. When a stress fracture is suspected, an MRI is necessary for diagnosis. Tears of the acetabular labrum are best seen on an MRI after the dye has been injected into the hip joint. This test is called an *MR arthrogram*. A *bone scan* is a special type of X-ray that is done after dye injection. It is less commonly used, but it may also show increased activity in the pubic bone (which suggests osteitis pubis or pelvic stress fracture) or the femoral neck (which suggests stress fracture).

Differential Diagnosis

The following is a partial list of some of the more important and common causes of groin pain in athletes.

Groin Pull

A groin pull occurs when there has been a strain or microtear of the adductor muscle tendon, which attaches to the pubic bone. These injuries are common in kicking sports such as soccer and rugby. Pain is located over the adductor tendon, which is located on the upper inner thigh or the psoas tendon, which runs in front of the hip joint. On physical exam, the adductor tendon is tender to the touch, and moving the hip away from the body causes pain (by stretching the tendon). No imaging is necessary to make the diagnosis. Treatment includes rest, anti-inflammatory medications such as ibuprofen for pain, and physical therapy directed at stretching and strengthening the adductor muscle.

Pelvic Avulsion

An avulsion occurs when a strong muscle contraction causes the tendon to partially tear off a piece of bone of the pelvis or femur where it attaches. These injuries commonly occur in younger athletes who are still growing. The psoas, adductor, hamstring, and quadriceps tendons can all pull away from the bone where they attach. These injuries cause a sharp pain and an audible pop. An X-ray may show that a piece of bone has pulled off of the pelvis or femur. An avulsion might not be seen on X-ray if the portion of the bone that pulled off was mostly made up of cartilage. Most of these injuries heal on their own without surgery as the area surrounding the tendon scars back into the bone. Crutches are recommended for a period of time as the avulsion fracture heals. Avulsions that involve large bony fragments that have been pulled far away from the bone may need to be surgically reattached.

"Snapping Hip"

An internal *snapping hip* occurs when a tight psoas muscle tendon snaps over the hip joint or over the inner part of the pelvis. This snap is usually audible and reproducible by the athlete, but it does not always cause pain. Snapping hip is commonly seen in dancers, gymnasts, and long-distance runners. If the snapping does not cause pain, no treatment is necessary. If the snapping becomes painful, it is likely that the psoas tendon or the bursa underneath has become inflamed. In these cases, the athlete is treated with rest, anti-inflammatory medications, physical therapy to stretch the psoas tendon, and, occasionally, corticosteroid injections into the psoas bursa. Surgery is rarely necessary.

Osteitis Pubis

Osteitis pubis is inflammation, irritation, or strain at the pubic bone, where the hip adductor tendon and rectus abdominal muscle attach. It is a repetitive trauma overuse injury commonly seen in soccer, hockey, and rugby players. Pain occurs at the pubic bone and is associated with kicking or jumping. It is thought to be related to an imbalance between the adductor and the rectus abdominus muscles. On physical exam, the patient reports tenderness over the pubic bone. Hip abduction (moving one leg away from the other) may exacerbate the pain. X-rays can show some bony changes at the pubic joint, but an MRI will more reliably show a swelling of the pubic bone. A bone scan that shows high uptake at the pubic bone is also used to make the diagnosis. Treatment includes rest; avoiding kicking, running, or jumping; anti-inflammatory medications; and physical therapy to correct the muscle imbalance.

Hip Stress Fracture

A stress fracture of the hip most commonly occurs in the neck of the femur bone. It is a repetitive, overuse injury that is often seen in female long-distance runners. Femoral neck stress fractures present with groin pain during weight-bearing or running activities. Diagnosis is usually made by MRI as X-rays may be negative. Athletes are usually treated with crutches and non–weight bearing for a period of time. No running is allowed until the stress fracture heals. Rarely, the stress fracture does not heal with time, and surgery is necessary to fix the fracture with screws and/or a metal plate.

Hip Impingement and Labral Tear

The hip, as noted, is a ball-and-socket joint. When the acetabulum (socket) or the femoral neck is large, they can bump into each other with extreme hip movements. Hip impingement can occur in athletes who move their hip to the end range of its motion. For example, as a ballet dancer kicks the leg above the head, the femoral neck can bump into the front of the acetabular socket. This impingement occurs at the location of the acetabular labrum. Over time, after repetitive episodes of hip impingement, a bony spur can form on the acetabulum or femoral neck. In addition, the increased stress on the labrum can cause the labrum to tear.

Athletes with hip impingement or labral tears present with groin pain made worse with flexing the hip and turning it inward. Physical exam shows a positive hip impingement test. While bony spurs may be seen on X-ray, an MR arthrogram is necessary to diagnose a hip labral tear. Initial treatment usually consists of physical therapy to stretch and strengthen the hip while avoiding activities that cause hip impingement. Surgery may be necessary if the groin pain continues after a few months of conservative management. Surgical treatment options include hip arthroscopy and open hip surgery, which attempt to repair the labral tears and remove the bony spurs.

Sports Hernia

Sports hernia is a relatively new and poorly understood cause of groin pain. It is seen commonly in hockey and soccer players. Similar to osteitis pubis, it is thought to be related to an imbalance between the abdominal and the adductor muscles. This imbalance places a shearing force on the pelvis and causes pain. On physical exam, there is often no hernia seen. The athlete usually has groin pain while doing a sit-up. In addition, pain is noted with resisted hip adduction and with coughing. X-rays, MRI, and bone scan are often completely normal. Physical therapy aimed at correcting the muscle imbalance may help, but pain often recurs. Many athletes require surgery, although recommended surgical treatments vary.

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See also Hip Flexor Tendinitis; Pelvic Avulsion Fractures; Snapping Hip Syndrome

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Groin Strain

In athletics, one often hears the terms *groin pull* and *groin strain. Groin* is the word usually used for the crease or hollow at the junction of the inner part of each thigh with the trunk and the adjacent region. *Groin pull* usually refers to minor tears of some muscle fibers without a major effect on the main muscle. *Strain* means stretching the muscle too far: A severe strain can often lead to the tearing of the muscle fibers (sometimes even the entire muscle separates from its bony attachment). A groin strain is a serious setback to a professional athlete and can potentially threaten his or her career if not handled properly.

Anatomy

Essentially, groin pull or strain denotes a strain or perhaps the tearing of the upper or proximal attachments or the fibers of the anteromedial thigh muscles or inner thigh (usually involving the adductor group—six muscles that stretch from the anteroinferior part of the pelvis bone to the linea aspera of the femur or, put simply, the muscles that run from the groin area down the inner thigh to the inner side of the knee; see Figure 1). The adductor muscles comprise the adductor magnus, adductor longus, adductor brevis, obturator externus, and gracilus. The most common muscle to be involved is the adductor longus. As is obvious from the name of the group, the main action of these muscles is to adduct the thigh, or to bring the legs together.

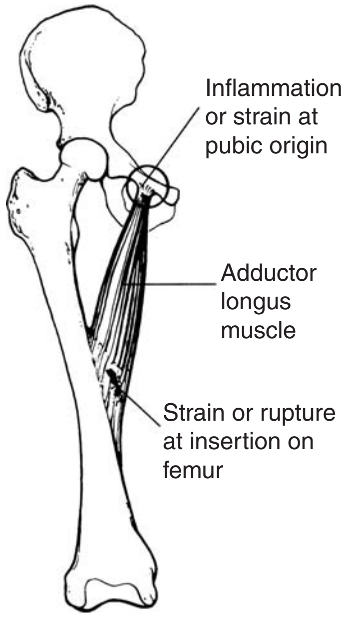

Figure 1 Groin Strain

Note: Groin strain commonly affects the adductor longus muscle, usually where the muscle tendon attaches to the thigh and sometimes where it attaches to the pubic bone.

Cause

Groin strain is usually the effect of one of the following on muscles that are weak or tight, or basically unconditioned:

- Resisted forceful abduction of the hip (outward movement of the thigh) or stretching of the adductors excessively (e.g., kicking a football)
- Putting sudden stress on the adductors, for example, a sudden change in direction
- Excessive overuse of the adductors at a given time
- A direct blow (kick or getting hit with a ball) in the groin

This condition is mostly seen in sports requiring sudden starts or bursts of speed, as in sprinters (due to the fast start), hurdlers, fast bowlers in cricket, footballers, and ice hockey players.

Predisposing/Risk Factors

Weak and tight adductor muscles, usually due to lack of proper conditioning in the prematch period, predispose to the development of the condition. Other factors include fatigue, overexertion, cold weather, and lack of proper warm-up.

Symptoms

Pain is the dominant symptom in this condition. It can take the following forms:

- A sudden sharp pain, which is felt during the exercise
- Tight or sore groin muscles (this symptom could be delayed till the next day)
- Pain on walking or movement of the thigh
- Pain and inability to bring the legs together (adduction)
- Pain on stretching the adductors
- Pain on resisted adduction (bringing the thigh to the midline from the side)
- Pain on resisted hip flexion (bringing the thigh upward toward the trunk)
- Bruising in the groin area (the area joining the abdomen to the thigh; this symptom could be delayed for a day or two)
- Swelling in the affected area (this too can be delayed by a couple of days)

- Sometimes a gap or swelling in the adductor muscles, indicating a tear

Grading of Severity

The condition is graded according to the severity of the pain and associated symptoms:

Grade I: There is discomfort, usually with the absence of any disability. There is no swelling. Recovery usually takes 2 weeks in this case.

Grade II: There is discomfort associated with inability to perform strenuous activities such as running. Some swelling or bruising may be evident. About 1 to 2 months may be required for recovery.

Grade III: Severe pain on walking. In severe cases, there may be pain at rest also. Significant swelling and bruising are often present. The patient may also experience muscle spasms. Recovery may take 3 months or more.

Diagnosis

Clinical Examination

- The presenting or main complaint is pain in the adductor area.
- Palpation or touching reveals tenderness or pain of the adductor muscles.
- *Provocative test:* Resisted adduction or inward movement of the thigh causes pain; sometimes a hip flexion or a bending thigh is also painful.

Imaging Studies

An imaging/radiograph of the hip joint should be taken to rule out avulsion or snapping of the muscle at the adductor tubercle. Magnetic resonance imaging (MRI) may be needed for exact diagnosis and grading of severity.

Treatment

First Aid

Athletes should be trained to recognize the symptoms and apply the RICE protocol: *r*est, *i*ce, *c*ompression, and *e*levation.

Injured athletes should be careful not to strain the muscle further, even if they have to use crutches or a stretcher. They can wear an elastic compression bandage on the upper thigh for compression, but they should be careful not to wrap the bandage too tight. The leg should be kept elevated above the level of the heart for the first 24 hours to prevent swelling.

A sports injury specialist should be consulted as soon as possible.

Professional Treatment

Treatment varies with the severity of injury. One or all of the following may be considered.

Initial Treatment

Rest. This is the cardinal principle in any groin injury. Adequate rest is often followed by complete healing of the muscle. The patient should be advised to avoid all activities that are likely to cause pain and even to shorten the stride or use support while walking.

Local cold pack/ice. Using ice or cold packs on the injury during the first 2 days is often very helpful in easing the pain and swelling. Ice should be applied for 15 to 20 minutes four times a day and should be wrapped in a towel to avoid direct application. Ice application can be extended for several days if necessary, and the process can be repeated after activity involving the affected area.

Medication. Oral nonsteroidal anti-inflammatory drugs (NSAIDs), such as ibuprofen, should be taken as prescribed by the doctor.

Subsequent Treatment

Stretching. Stretches are employed in both prevention and treatment. Gentle stretching is advisable, although care must be taken not to overdo it as excessive stretching may be counterproductive. A gentle pulling sensation is the aim, but the stretch should not be painful. Stretching should be done in the recovery period and can be done several times a day. Stretches include the following:

- *Squatting adductor stretch:* The patient squats with the arms between the legs; the knees should be moved outward by pushing apart with the elbows.
- *Butterfly stretch:* The patient sits with the knees bent and feet together, grasping the feet with the hands and stretching the knees toward the ground.

- *Adductor stretch:* The patient stands with leg out to the side, bending the knee of the leg under the body to stretch the muscles of the inner thigh of the opposite leg.
- *Cross-legged stretch:* The patient sits in a chair with one leg crossed over the other, pressing the knee of the crossed leg toward the ground.

Local application of heat. While a cold compress is helpful after activity, a hot compress is of benefit before any activity is undertaken (e.g., stretching), to soften the area and reduce any chance of further aggravation of the injury. However, use of heat should be started in the recovery period, not in the period immediately following the injury.

Physiotherapy. Ultrasound treatment, infrared treatment, specific exercises, and massage by trained physiotherapists under the supervision and guidance of sports injury specialists or rehabilitation specialists are often of value in speeding up the recovery period and preventing complications.

Strengthening exercises. These are added gradually when a fair amount of recovery has taken place, but they must be done under supervision. These include adductor and abductor strengthening as well as pelvic stabilization exercises, including lunges, squats, extensions, and so on, and also core strengthening exercises that target muscles that are hard to get to, including abdominal and lumbar stretching. These are usually done with a large exercise ball.

Surgery. Conservative treatment usually works even in the most severe cases, but in rare cases, one may have to resort to surgery to reattach the torn ends of the muscle.

Prevention

The most important factor in the prevention of this injury is the proper conditioning of athletes, especially those who participate in sports where groin injury is more likely. To ensure hip strength, athletes should warm up properly before any exercise. It is also important to incorporate stretches and strengthening exercises into the preseason training routine.

Daniyal Asim Khan and Waleed Hassan

See also Groin Pain; Groin Tendinitis; Groin/Inguinal Hernia

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Groin Tendinitis

Injuries to the soft tissue around the hip and pelvis are among the most common athletic injuries, and the majority of these cases involve musculotendinous strains and inflammation. Hip, pelvic, and groin injuries can present with similar symptoms, so it is often challenging to differentiate between problems that occur within the hip joint, such as labral tears and femoroacetabular impingement, and those that occur outside the hip joint, such as iliopsoas tendinitis, iliotibial band syndrome, femoral neck stress fractures, and adductor strains. *Groin tendinitis* refers primarily to an inflammation of the iliopsoas tendon as it crosses in front of the hip joint and inserts on the femur.

Common causes of iliopsoas or groin tendinitis include acute trauma and overuse from repetitive hip flexion. Groin tendinitis occurs most frequently in dancers, gymnasts, runners, rowers, and soccer players.

Anatomy

The iliopsoas is actually made up of two muscles, the iliacus and the psoas major, which are separate near their points of origin in the abdomen but converge and form a single tendon, known as the *iliopsoas tendon*, as they pass out of the abdomen under the inguinal ligament and across the anterior aspect of the hip joint. The iliacus muscle originates on the iliac fossa on the inside of the pelvis as well as on the anterior inferior iliac spine (AIIS). Conversely, the psoas major originates on the lumbar vertebrae, and together, the combined iliopsoas tendon inserts onto the lesser trochanter of the femur. About 40% to 50% of the population also has a psoas minor muscle, which also originates on the lumbar vertebrae but inserts on the iliopectineal arch and, thus, does not form part of the iliopsoas tendon. All three muscles are innervated by nerves that come off the lumbar plexus. The main purpose of the iliopsoas is to act as a hip flexor, but it can also aid in trunk flexion and lateral rotation of the hip. It is prone to shortening and tightening if it is not regularly stretched, which can in turn lead to increased lumbar lordosis and anterior pelvic tilt.

There is also a small sac of fluid, called a *bursa*, that lies under the iliopsoas tendon and acts as a cushion to reduce friction as the tendon moves over the bones. When the tendon is inflamed, the bursa often becomes inflamed too, but the symptoms and treatment are the same.

History

The two main mechanisms of injury in groin tendinitis are acute injury and overuse injury. Acute injuries often occur when the iliopsoas undergoes rapid flexion against resistance (eccentric contraction) or, less commonly, from direct trauma to the muscle or tendon. Conversely, overuse injuries typically occur with activities that require repeated hip flexion or outward rotation of the thigh, such as ballet, rowing, soccer, gymnastics, and running (especially uphill), and even training with weights. Overuse of the iliopsoas can lead to inflammation of the tendon, and the risk of painful inflammation is increased if the iliopsoas is tight. It is not uncommon for adolescents, especially during a time of rapid growth, to develop tight hip flexors as their bones grow faster than their muscles and tendons do. However, adults are still at risk for tightness in their iliopsoas too, especially those with an anterior pelvic tilt or increased lumbar lordosis (an increased curve in their lower back) and athletes who do not regularly stretch the iliopsoas.

Dancers are especially at high risk of developing a related problem known as "snapping hip" syndrome, which can be due to poor technique. In snapping hip syndrome, an audible pop or snap can be heard as the iliopsoas tendon literally snaps over the iliopectinial eminence or femoral neck. Most cases of snapping hip are not painful, but they may become painful if the muscle is not stretched or with continued use without correction of the poor technique that may be causing the snapping. Snapping hip secondary to the iliopsoas is also referred to as "anterior" or "internal" snapping hip, which should be differentiated from "lateral" or "external" snapping hip, which is due to the iliotibial band snapping across the greater trochanter on the outside of the hip.

The pain associated with groin tendinitis is usually in the front of the hip and typically is only present when flexing or outwardly rotating the hip, but over time, it may progress to the point where it occurs during daily activities and then even at rest. Patients may complain of pain with sports-related activities, such as running and kicking, as well as non-sports-related activities, such as putting on socks and shoes, rising from a chair, and walking up stairs or on inclines. Sometimes the pain may even radiate down the front of the thigh toward the knee.

Physical Examination

Since there is such a broad array of potential causes of groin pain, physical examination of the athlete who presents with this symptom should always include a thorough examination of the abdomen, hip, and groin.

Inspection may often be normal, but it may occasionally yield an increased anterior pelvic tilt, a slightly flexed and externally rotated hip. During normal walking, stride length may be shortened on the affected side as well, and in severe cases, a limp may be noted.

There may be tenderness to palpation in the groin area over the iliopsoas itself and at its insertion at the lesser trochanter of the femur.

There are several maneuvers to elicit pain in the hip that would suggest that the pain is due to iliopsoas tendinitis. One way is to stretch the iliopsoas, and the other is to make it contract and flex against some resistance.

The best way to perform a stretch test of the iliopsoas is to have the patient lie on his or her back and drop the leg on the affected side over the side of the table, effectively extending the hip backward. This sometimes causes pain in the groin, but the iliopsoas can be targeted and stretched even more if the foot is slowly brought away from the table, which rotates the hip inward.

There are two ways to stress the iliopsoas by actively making it contract against resistance. One way is to have the patient lie on his or her back with the unaffected leg straightened out and the affected leg crossed over it so that the outside of the foot on the affected side lies on top of the knee on the unaffected side. This is sometimes referred to as a "frog position" or a "figure-four position." Then, the examiner should place his or her hand on the knee of the affected leg and ask the patient to bring the knee up and toward the midline while keeping the foot resting on the knee of the unaffected side. If this causes pain, it is suggestive of iliopsoas tendinitis. The other way to test for iliopsoas is to have the patient either seated with the legs straight or lying down, again with the knees straight, and to ask the patient to raise his or her leg on the affected side. If the patient experiences pain with the leg about 15° off the table, it is suggestive of iliopsoas tendinditis. This test is commonly referred to as the Ludloff sign.

Last, a patient with groin tendinitis may also experience groin pain when his or her hip is moved by the examiner to a point of maximum flexion such that the knee is over the abdomen or chest. This maneuver is referred to as passive hyperflexion of the hip, and the patient should be relaxed and not assisting the examiner with this movement.

Diagnostic Imaging

Although tendons cannot be seen on plain radiographs (X-rays), X-rays are usually the first imaging study obtained to rule out other, more serious causes of groin pain. they can show problems with the bones of the pelvis, hip, and upper leg, and they would be normal in cases of isolated iliopsoas tendinitis.

Magnetic resonance imaging (MRI) is generally considered to be the best test for evaluating hip pain because it can examine both bone and soft tissue structures that may be the source of pain. An MRI scan can show swelling and thickening of the tendon, inflammation, and tendon tears.

Ultrasound can also be used to evaluate the iliopsoas tendon, which may appear thickened and surrounded by fluid in cases of tendinitis. However, this technique is highly user dependent and requires a very knowledgeable and experienced technician to make an accurate diagnosis.

Treatment

Once iliopsoas tendinitis has been diagnosed, the preferred initial treatment includes "relative rest," anti-inflammatory medications, and physical therapy.

Relative rest implies avoidance of the sports and activities that cause pain and usually needs to be adhered to for 2 or 3 weeks. During this time, nonsteroidal anti-inflammatory drugs, or NSAIDs, should also be taken on a scheduled basis, either two or three times a day with meals for 5 to 14 days, provided the patient can tolerate this group of medications. When taken on this type of schedule, NSAIDs can act to both decrease pain as well as to decrease inflammation. Physical therapy should address the stretching of the hip flexors and external rotators and also the strengthening of these muscles and the adductors and internal rotators of the hip. Core and peripelvic strengthening to reduce excessive lumbar lordosis or increased curvature in the lower back should also be addressed, because the psoas muscle originates on the lumbar spine before traveling through the pelvis and across the hip joint. A physical therapist may also massage and apply heat to the iliopsoas, which may decrease pain and assist in recovery. As pain and inflammation subside, the patient can gradually begin increasing his or her physical activity, with progression to sport-specific activities and eventually to full, painfree participation. To prevent recurrence, care must be taken to correct poor technique or the biomechanical issues that may have initially led to the groin tendinitis. Furthermore, continued compliance with a maintenance strengthening and stretching program is also of paramount importance to prevent reinjury.

Most cases of groin tendinitis resolve with the aforementioned interventions; however, some chronic cases of tendinitis that fail to respond to these more conservative measures may require either a steroid injection or, rarely, surgery. Corticosteroid injections into the iliopsoas tendon sheath under fluoroscopic guidance may provide significant relief in these recalcitrant cases. These injections may be given up to three times and in the setting of relative rest and stretching. These injections usually bring about resolution of symptoms, but in the rare cases that they do not, surgery—with either complete or partial release of the iliopsoas tendon—is indicated. Both approaches have produced good results with regard to pain relief with minimal weakness postoperatively, such that the majority of patients are able to return to their previous athletic activities.

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See also Femoral Neck Stress Fracture; Femoroacetabular Impingement; Groin Pain; Groin Strain; Groin/Inguinal Hernia; Iliotibial Band Syndrome

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Groin/Inguinal Hernia

A *hernia* occurs when a structure or organ contained in one body cavity passes through the wall of tissue that normally separates it from another cavity. Hernias are described and classified according to where the structures pass through the weakened body wall. The most common areas of the body to have a hernia are the groin—the site of inguinal hernia—and the abdominal regions. The condition known as "sports hernia" manifests as pain in the groin area, but it is actually not a true hernia, as described below.

There are a few common types of hernias. An inguinal hernia occurs in the groin region; the inguinal canal is a small opening in between the layers of the abdominal muscles. These hernias can be further classified into indirect and direct hernias. An *indirect inguinal hernia* develops at the internal ring, where the spermatic cord in males or the round ligament in females leaves the abdomen. Indirect hernias originate lateral to the inferior epigastric artery. Most inguinal hernias are thought to be congenital; that is, they were formed during abnormalities in fetal development. The hernia may have been there since birth and then may have risen with instances of increased abdominal pressure.

A *direct inguinal hernia* originates at the Hesselbach triangle, formed by the inferior epigastric vessels laterally, the rectus abdominus muscle superiorly, and the inguinal ligament inferiorly. Many of these hernias are also congenital, but some are thought to arise from weakness in the floor of the inguinal canal. Weakness in the floor of the canal may be caused by heavy lifting; however, studies indicate that the relationship between heavy lifting and hernias is not clear.

Inguinal Hernia

Symptoms

Groin hernias may present with a range of manifestations, from no symptoms at all to very severe pain. The most common symptom is mild pain or a heavy, pressure-like sensation when lifting or straining, causing an increase in abdominal pressure. These sensations are caused by the contents of the hernia trying to move through the opening or weakened body wall. The pain is usually resolved by lying down or by stopping the straining activity. People who stay on their feet for prolonged periods of time or do repetitive lifting may notice that their symptoms are worse at the end of the day. Some hernias present as a bulge in the groin, thigh, or abdominal areas. The most common complaints by the athlete and the patient are pain and mass in the groin area.

Diagnosis

Physical Exam Findings

The easiest way to demonstrate a hernia is to examine the patient while he or she is standing. Using one or two fingers, the external ring is palpated while the patient is asked to cough or strain. In women, the femoral canal should be examined as well. This area is found at the midpoint of the inguinal canal by locating the femoral artery. If a hernia is demonstrated, the examiner will feel a small pressure or bulge against the fingertips, sometimes described as a silky sensation against the fingers.

Imaging

Hernias may be demonstrated by a variety of imaging techniques. A herniography involves injecting a contrast medium or dye into the lower abdominal region to visualize the hernia. However, this technique is invasive and involves exposing the patient to a needle puncture and radioactive material. Ultrasound and magnetic resonance imaging (MRI) have been shown to be fairly sensitive and specific in detecting groin hernias as well.

Treatment

The definitive treatment of groin hernias is surgical repair. The reason for this is primarily to prevent the main serious complications of hernias, strangulation and incarceration. An *incarcerated hernia* is when the contents of the hernia are trapped and cannot be pushed back into the inguinal canal or reduced. A *strangulated hernia* is a condition in which the blood supply to the contents of the hernia is reduced. This condition is an emergency; without blood flow, the hernia contents lack oxygen and may become necrotic; in other words, the tissue may die. Surgery within hours of this condition usually has a favorable outcome. There are many surgical techniques available to repair a hernia. They include open repair through an incision and laparoscopic repair.

Recovery/Return to Sports

Opting to have surgery for a groin hernia allows the patient to return to previous activity fairly rapidly. In general, people in sedentary professions may return in 10 days. Heavy lifting (more than 25 pounds [34 kilograms]) is not recommended for approximately 6 weeks.

Sports Hernia

A *sports hernia*, so called, is defined as any condition causing groin area pain. This common term can be misleading, as there is no actual hernia on physical exam. Some define the sports hernia classically as weakening of the posterior inguinal wall. This condition is also known as *Gilmore groin*, *sportsman's hernia*, *hockey groin*, and *athletic pubalgia*.

Causes

Sports hernias appear to be more common in men. They occur more often in sports where the athlete leans forward in an "athletic stance"—that is, in football, soccer, hockey, and rugby. Any sport where there is high-speed twisting, turning, or torquing of the groin likely contributes to this condition. One proposed mechanism is that hip abduction, adduction, and flexion-extension with associated pelvic motion place a shearing force across the pubic symphysis. This leads to stress on inguinal wall musculature perpendicular to the fibers of the fascia and muscle.

Numerous pathologic abnormalities have been reported, including tears of the external oblique aponeurosis with injury to the inguinal nerve and its branches. Other reported injuries include abnormalities at the insertion of the rectus abdominus muscle, avulsions of the internal oblique muscle fibers at the pubic tubercle, and tears of the conjoined tendon or transversalis fascia. There has also been an association with osteitis pubis, a degenerative condition of pubis symphysis and surrounding muscle insertions.

Symptoms

The diagnosis of a sports hernia is primarily clinical in the patient or athlete who has symptoms of groin area pain but no evidence of hernia on exam. The symptoms are worse with sudden increases in intra-abdominal pressure, such as during sneezing, coughing, or bowel movements. The symptoms may also be reproduced by performing sit-ups or crunches.

Diagnosis

This is primarily a clinical diagnosis, but many imaging techniques may be useful to rule out other conditions that can mimic a sports hernia. Plain radiographs (X-rays) may detect osteoarthritis or stress fractures. A technetium-99m bone scan may show an increased uptake in the pubis region and can rule out osteitis pubis. An ultrasound scan may demonstrate occult hernias. MRI may show abnormalities in the musculature, bursitis, stress reactions, and many other conditions. Herniography is not usually used for detecting sports hernias.

Treatment

Treatment of the sports hernia is somewhat controversial as there is no true hernia. Surgical intervention is considered the standard of care, despite its not being well studied; clearly, this is an area for further investigation.

It is reasonable to have a period of rest for the athlete for 6 to 12 weeks. Treatment with rest should be accompanied by the use of nonsteroidal anti-inflammatory drugs (NSAIDs), ice, and physical therapy. Often, the athlete will want to return to play in a more timely fashion and will opt to have surgery. Surgery can be performed as an open approach through an incision or by a laparoscopic approach. There are many surgical techniques used for repair; however, most involve reinforcing the abdominal musculature surrounding the inguinal area or placing mesh supports. Since there are many different pathologies that can explain the groin pain, treatment is specialized around each diagnosis.

Recovery/Return to Sports

Return to play after sports hernia repair has not been well-defined. There are varying reports of postsurgery rehabilitation programs, both for open and for laparoscopic repairs. In general, laparoscopic repair offers earlier return to activities of daily living, as well as return to pre-injury activity levels. In general, sharp, sudden movements are avoided early in the rehab process. Deficiencies in core and leg strength, flexibility, and endurance are addressed early on. Walking is encouraged early in the rehabilitation process, with straight-line jogging and running by 3 to 4 weeks postoperatively. Sprinting and cutting are initiated by around 3 weeks postoperatively. Overall, return to competitive activity is allowed between 6 and 8 weeks after surgery. There have been other reports of earlier return to play after laparoscopic repair.

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See also Field Hockey, Injuries in; Football, Injuries in; Rugby Union, Injuries in; Osteitis Pubis; Soccer, Injuries in

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Group Fitness Instructor

A *group fitness instructor* (GFI) is anyone who leads three or more people at a designated time in a class with the objective of improving one or more health components. The specialized fitness classes led by an instructor focus on one or more of the following components of fitness: strength, endurance, power, flexibility, stability, and balance.

These components are covered in a class lasting from 15 minutes to 2 hours. On average, most GFIs lead classes that are 1 hour in length. Instructors in an average group fitness class may use the following format:

1. *Warm-up/movement preparation:* This is always covered at the beginning of class; otherwise the risk of musculoskeletal injury is high during the later portions of the class. This portion of the class takes 3 to 10 minutes, depending on the fitness components the instructor must focus on during the remainder of the class.
2. *Body of the class:* On the completion of the warm-up, the instructor will lead participants through exercises that focus on the overall fitness goals of the class. The instructor leads the class through auditory, visual, and proprioceptive cueing. Auditory instruction includes the explanation of the movement and the exercise's duration. Duration can refer to the number of repetitions of the said movement or the length of the movement pattern or exercise (time under tension of the working muscle groups). Visually, the instructor can show the participants how to execute the movement pattern or exercise by positioning himself or herself in front of all participants. This way, participants can replicate the movement pattern the instructor is demonstrating. Auditory and visual instructions are usually done in combination throughout the group fitness class. Instructors usually give proprioceptive instruction: They give participants the challenge of not allowing certain parts of the body to move during the movement pattern. An example of proprioceptive feedback would be to put a towel roll on the lower back of a class participant while he or she executes a standard push-up and instructing the participant not to allow the towel roll to fall off the lower back while executing the push-up. This type of feedback keeps the participant more cognizant of his or her form. The body of a 1-hour group fitness class will take approximately 40 to 45 minutes, or 75% of the total class time, to meet the participants' fitness goals.
3. *Cooldown/stretch:* This is a very important portion of the group fitness instructor's class because it allows the participants to reduce their increased heart rates, built up during the body of the class. This will reduce the onset of delayed muscle soreness and venous pooling of blood in the extremities. Traditional static stretching is generally the mode of flexibility that instructors encourage participants to employ.

An instructor leads an exercise class at the gym.

Source: Can Stock Photo.

GFIs are sought after in all major fitness centers throughout the world due to the high utilization of group fitness classes and the class's capability to retain membership. Most GFIs are highly motivated individuals with the ability to lead people, instruct participants well, and keep the participants motivated throughout the class. Personality traits of instructors vary depending on the format and type of class. Most high-intensity and high-volume classes, such as step aerobics, tend to attract energetic, zealous instructors who are passionate about that style of fitness. Low-impact group fitness classes, such as yoga, tend to draw instructors who are more subdued.

Classes Led by Group Fitness Instructors

The types and trends of group fitness have changed significantly in recent decades. Most people associate group fitness with step aerobics; however, group fitness instructors today offer a wide variety of classes. The following are just a few of the classes that instructors teach, and all require training and certification to lead:

- Stationary cycling
- Step aerobics
- Yoga
- Pilates
- Zumba
- Kettlebell conditioning
- Suspension training
- Boot camp
- Abdominal/core conditioning

All or most of these classes require instructors to have a third-party certification, as well as a certain number of hours of continuing education credits (CECs), to be considered well versed in class design and exercise progression for the participants.

Certifications

There are many certifying bodies for group fitness instructors. However, the most creditable and thorough for aerobics classes are the Aerobics and Fitness Association of America (AFAA) and the American Council on Exercise (ACE). These two certifying bodies have met the necessary requirements to be nationally accredited. National accreditation is given to third-party certifying bodies through the National Commission of Certifying Agencies (NCCA). Specialized group fitness systems such as yoga, Pilates, stationary cycling, and Zumba have specific course requirements that demand hundreds of hours of training and practice for a candidate instructor to be considered adequate to teach participants in classes.

The costs of becoming a group fitness instructor and maintaining certification will vary not only with the credibility of the certifying body but also with the specialization of the group fitness class and the class's popularity. The requirements for maintaining the certification constitute an additional expense, as instructors must go to seminars, conferences, and courses to maintain the continuing education requirements.

Most fitness centers that hire group fitness instructors require them to be CPR (cardiopulmonary resuscitation) and AED (automated external defibrillator) certified and to have the specific certification that is needed for the class they will be leading. The popularity of the class, the years of experience of the group fitness instructor, and, most important, the quality of instruction provided will determine his or her level of compensation for services rendered. Many group fitness instructors teach as independent contractors for one or more fitness centers in an area that is convenient to their home or primary place of employment.

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See also Aerobic Dance, Injuries in; Preventing Sports Injuries

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Growth Hormone

Human growth hormone (HGH) is an anabolic hormone that has become very popular recently among elite athletes as a performance-enhancing drug. It has been shown to increase lean muscle mass and strength. It seems to assist an athlete in recovering from injuries or strenuous workouts and is of particular interest for professional athletes who endure long, grueling seasons. There have been several debatable attributes assigned to HGH, and some consider it an antiaging wonder drug. It is banned in all professional sports and in international competition, but it is currently almost impossible to detect. HGH is suspected to have been used in almost all sports, from football to baseball to track-and-field events, and even golf. It is likely used at all levels of competition, including high school athletics.

HGH is a naturally occurring peptide hormone that is produced in the pituitary gland throughout a person's entire life. In its naturally occurring (endogenous) form, it is referred to as *somatotropin*. The synthetic form is referred to as recombinant growth hormone, or rHGH. The highest levels of endogenous (naturally occurring) HGH are found during puberty and early adolescence. Endogenous GH goes through cycles of peaks or pulses throughout the day. Peaks last around 10 to 30 minutes, and the most reliable elevation occurs approximately 1 hour after the onset of sleep.

Anecdotal evidence and well-controlled clinical trials have shown an increase in lean muscle mass in adults. It is difficult to study, however, for the same reason that it is difficult to test for in athletes. HGH has a very short half-life, and blood levels vary widely for each person at different times of the day. They vary by age but generally decline with each decade of life. In addition, the exogenous (injected) form of HGH is identical to the natural form, so it is difficult to determine if someone who is found to have a high level of it has achieved it through doping. The urine levels of HGH are more than 100 times lower than they are in the blood. This alone makes athletic testing more difficult, as it requires more expense and equipment to effectively test, apart from concessions from professional unions for testing consent.

HGH's popularity among younger athletes and amateur athletes may be limited by its high price. Obtaining HGH via the Internet is disturbingly easy, but the cost is likely to be around $1,000 to $2,000 per month as of 2008.

Although HGH is a legal medication with therapeutic benefits, it is illegal to distribute or administer it without a prescription or for treatment protocols that are considered experimental. Although there have been antiaging claims made for this hormone and there exist antiaging clinics that have prescribed it, doctors or people taking it for these reasons or for athletic performance can be prosecuted.

The conditions for which HGH is an accepted and effective treatment include congenital short stature and GH deficiency in children, chronic renal failure, Prader-Willi syndrome, and Turner syndrome. Athletes who use HGH for performance enhancement may be using 10 to 20 times the normal amount, and the long-term effects of this are still unknown. Known potential risks include a significantly higher rate of joint pains, carpal tunnel syndrome, and diabetes. Increased skull circumference, peripheral neuropathy, hypertension, and behavioral changes have also been noted. There are also concerns that it could contribute to certain types of tumors.

Michael O'Brien

See also Doping and Performance Enhancement: A New Definition; Doping and Performance Enhancement: Historical Overview; Doping and Performance Enhancement: Olympic Games From 2004 to 2008; Performance Enhancement, Doping, Therapeutic Use Exemptions; World Anti-Doping Agency

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Gymnastics, Injuries in

Gymnastics is both a competitive and a recreational sport. Injuries, which are influenced by age and gender, are often unique to the sport because of the intense physical demands and long hours of training needed to successfully complete routines on the floor, the balance beam, the vault, and the apparatus.

The gymnastic skill level, the training environment, and the methods used to build strength, flexibility, and endurance in the gymnast are all factors that influence both the number and the types of injuries that occur. The advanced gymnast needs to learn an increasingly difficult level of skills and complicated maneuvers, often done in combination, to develop a competitive routine.

Training for gymnastics, starting at a very young age, can produce world-class athletes at ages as young as 13 years. However, the intense and extreme physical demands of training and competing in the sport create a potentially injury-prone environment for the athlete at any age. Understanding the growth and development of muscles, bones, and joints in the developing gymnast can be helpful in recognizing the types of injury patterns typical of the sport.

Epidemiology

Gymnastics clubs and schools create opportunities for participation in the sport, starting as young as age 4 and continuing through adulthood. Male and female injury rates are high among competitive gymnasts; in women, it's the highest of all sports. In the United States, more than 900,000 athletes participate in gymnastic clubs and competition. Reportedly, 86,000 injuries are treated annually in children 18 years of age and younger. The injury rate recorded among elite gymnasts has been as high as 7 per 100 during the competition season.

Many causes of injury are related to the long hours and frequent training sessions required to compete in the sport. Complex and often risky skills expose the arms and legs, as well as the spine, to extreme forces and explain why injuries occur.

Most injuries are mild to moderate and affect the foot, ankle, knee, hand and wrist, elbow, shoulder, and spine. Tears of the ligament (the tough bands of tissue that connect bones together) and sprains, tears of muscle-tendon groups, and strains and stress injury to the bone make up this group of injuries. Stress fractures of the leg, arm, and spine are usually caused by overtraining. In younger gymnasts, growing and developing bones and joints in the arms and legs are vulnerable to more serious injuries, such as fractures. Knowing the nature of stresses each region of the body is exposed to can help in recognizing potential injury patterns in gymnastics. For example, different types of injures can be characteristic of floor, vault, and apparatus work.

Upper Extremity

The dominant use of the arms to support the body through various moving and stationary positions is unique to gymnastics. As a result, the large and small bones and joints of the hand and wrist are very prone to injury. The high incidence of wrist pain is due to the use of the upper extremity to balance, push, hold, and absorb forces repeatedly on both the floor surface and the apparatus. Of those training and competing in gymnastics, 88% of males and 55% of females reportedly experience episodes of wrist pain that limit practice time and performance. Upper extremity injury is more common in male gymnasts because four of the six gymnastic events they compete in require dominant use of the arm.

In gymnastics, skills on the apparatus, such as the bars and rings, which require swinging with a release-and-catch motion, can expose the hand and wrist to torsion and shear and compression forces.

Source: Can Stock Photo.

Hand and Wrist

The gymnast's hand is positioned flat for handstand support in both static hold and dynamic, or moving, positions when tumbling on the floor, performing on the balance beam, and vaulting. The hand is held in a firm grip/supportive position while using the apparatus, the pommel horse, rings, and uneven, parallel, and high bars. The small bones of the wrist and the ends of the distal radius and ulna, the two long bones of the forearm, absorb stress repetitively with the arm fully extended as the hand balances the body. This position exposes the wrist, its small bones, and the lower ends of the radius and ulna to body forces and impact loads that far exceed the body weight.

Tumbling and vaulting generate extreme forces to the hand and wrist when the entire arm and shoulder are fully extended. In gymnastics, the wrist's smaller bones are placed in opposition to the larger bones at the end of the forearm, the radius, and the ulna. A variety of injuries can occur from these and other potentially deforming forces from overextended positions the hand supports on apparatus such as bars and rings. Skills on apparatus such as these, which require swinging with a release-and-catch motion, can expose the hand and wrist to torsion and shear and compression forces. Injury can occur to bone and cartilage surfaces of the wrist joint and the structures that support the wrist, including the ligament tissue and tendons crossing the wrist joint. A strain to the muscles that provide supportive control for both static and dynamic gymnastic skills can also occur along the forearm.

Compression forces to the small individual wrist bones, called the *scaphoid*, *capitate*, and *lunate*, can result in fractures, stress fractures, and stress reactions around the wrist joint. With the arm in the extended position, forces generated along the radius and ulna onto the wrist press these structures together, and repetitive exercise, over time, causes mechanical failure and leads to an inflamed or painful wrist joint. Stretching and twisting motions can tear ligaments and cartilage structures. Repetitive, very small injuries to these structures over time can result in disturbances in growth patterns in the bone and lead to chronic pain.

In the skeletally immature gymnast, both male and female, wrist pain is of particular concern. Injuries to the growth plate of the distal radius and the articulating small bones, tendons, and ligament structures of the wrist occur acutely, all at once, or gradually over time. This is of particular concern during the years when the skeleton undergoes rapid growth. During this vulnerable time, the growth center of the distal radius, or epiphysis, is at greatest risk for damage and for the development of abnormal growth patterns. With long-term and repeated stress, normal bone growth patterns can be suppressed, and at the time of skeletal maturity, the gymnast may have an irreparable deformity and chronic pain.

With wrist injuries, X-ray or magnetic resonance imaging (MRI) studies are frequently used to diagnose the cause of an athlete's acute or chronic pain symptom. Accurately diagnosing a distal radius growth plate at risk of developing growth disturbances relies on images of the epiphysis best seen by X-ray and MRI studies. X-rays show stress reactions in the developing bones' epiphysis. Widening of the growth plate, bone chips, bone spurs, and abnormal ratios of length between the ends of the radius and ulna are the abnormalities that can be seen in X-ray studies of a painful wrist.

Forearm

As training aids and to improve their advanced swing skill performance, gymnasts use wrist splints and handgrips. Using doweled grips for difficult skills while training on the rings and bars can help improve their handhold for greater strength and support. The drawback of this is that the gymnast is exposed to a greater risk of fracture to the forearm bones, radius, and ulna. The gymnast also faces an increased risk of a sprained wrist and potential injury to the growth centers at the end of the radius.

Forearm injury is mostly the result of powerful and sustained efforts of the related muscles to maintain grip while the gymnast performs skills on the apparatus. Pommel horse training for men can injure muscular attachments to the periosteum of bone in the forearm and cause pain, limiting the athlete's ability to grip. This type of injury results in what is called *forearm splints*. Ongoing stress without appropriate rest can also lead to stress fractures or stress reactions in the bones of the forearm. An accurate diagnosis of the cause of forearm pain is done by MRI if an X-ray is negative for skeletal changes.

The hand exerts a powerful muscular effort while gripping apparatus to complete advanced swing skills. Tears and ruptures of tendons and supporting connecting tissues at either end of the forearm are the result of large tensile loads against muscular resistance. A rupture of the biceps tendon at its attachment below the elbow is an example of a major tendon injury. Surgery to reattach the tendon to the bone is required to repair this form of injury.

Elbow

Elbow pain and the accompanying symptoms from injury, such as swelling and loss of range of motion that don't allow for full extension of the arm, often limit the gymnast's ability to position the body through a handstand balance, something that is inherent to the successful execution of acrobatic skills.

Acute and often serious injuries to the elbow joint can occur from bearing weight on an arm that is outstretched from a completed maneuver on the apparatus, or from tumbling or vaulting. Dislocations; fracture dislocations; growth plate fractures; osteochondral fractures, identified as cartilage breaking with its bone attachments inside the joint; ligament tears; avulsion fractures, or ligament attachments that fracture bone near the elbow joint; and fractures of the bone that separates the muscle attachments near the elbow joint are all injuries that can occur as a result of gymnastic training or competition.

The elbow joint is forcefully extended when doing a basic tumbling skill called a *handspring*. Forward and backward handsprings are integrated into combinations of acrobatic skills performed as floor exercises, on beams, and on vaults. Handsprings can produce large compressive loads at the near end of the radius against the lower end of the humerus called the *capitellum*.

Repetitive compressive loads and direct trauma to the extended elbow over time can lead to small localized injuries to the end of the humerus at the elbow joint and cause an area of the cartilage and bone to fragment. This discrete region of bone and cartilage causes both pain and catching or locking sensations and sometimes becomes loose inside the elbow joint. *Osteochondritis dissecans* of the capitellum is the term used to characterize these disorders. Surgical treatment for this is aimed at restoring normal anatomical structure and biology to the surfaces of the elbow joint. Pinning cartilage and bone fragments that are fractures, transferring healthy cartilage and bone to the joint, doing an arthroscopy simply to remove inflamed soft tissues, or smoothing irregular joint surfaces all help stimulate healing.

Gymnastic routines that expose the skeletally immature athlete's elbow joint to repetitive extensions may result in injuries to the near end of the ulna, also called the *olecranon*. Continued stress to its growth center, by using the triceps muscle to hold a stable elbow position for the arm, can cause stress reactions, fractures, and abnormal growth patterns.

Most injures to the wrist and elbow joints can be managed by periods of rest followed by sharply reducing the volume of provocative skills and then gradually reintroducing them in training sessions. Failing to manage an injury can result in long-term problems in the growing bones and joints and chronic pain disorders. Restricted joint mobility and swelling, loss of strength, localized tenderness, and inability to bear weight without painful effort are all indications of injury. In such cases, abnormal patterns of growth can be detected using diagnostic imaging, such as an MRI, of bone and cartilage.

Shoulder

The shoulder girdle, made up of the shoulder blade, the upper end of the humerus, and all the muscle, tendon, and ligament groups that provide support between the bone structures, is vulnerable to injury from traumatic falls from the apparatus or technical mishaps. The male gymnast's shoulder is exposed to tremendous centrifugal forces from the swinging events performed on the still rings, the parallels, and the high bars. Female gymnasts experience the same type of exposure on the uneven bars. More advanced skills, often practiced with handgrips, expose the gymnast to an even greater risk of injury.

The shoulder joint, formed by the humerus sliding and rotating with the scapular surface referred to as the *glenoid*, is vulnerable to forces that misalign the joint. This type of movement places the shoulder's interconnecting soft tissue support structure, called the *joint capsule*, under strain. Acute injury to the capsule can separate it from its attachments to the glenoid, called the *labrum*. Tears of the labrum are also seen at the attachment of the long tendon of the bicep muscle. Surgery, usually arthroscopic, is required to repair these types of injuries.

A dislocated shoulder is one of the most dramatic and common types of shoulder injury a gymnast can experience. A torn labrum and torn ligament tissue within its structure, or torn from the humerus, can make the shoulder joint unstable. Less severe excursions of the humerus are called *subluxation*. Recurring subluxation of the humerus results in repeated injury to the muscles, tendons, and nerves of the shoulder girdle, which leads to pain. Gymnastic performance nearly entirely depends on the stability of the arm. Surgery is almost always required to restore stability following an injury to the shoulder joint capsule, or labral attachments.

Other types of pain disorders of the shoulder girdle include muscle and nerve injury from strain when the gymnast uses resistance against the forces of inertia during swing maneuvers. Similar types of injury to the rotator cuff can cause tendinitis. Pain is experienced at the top of the humerus from impingement of the rotator cuff against the top of the scapula as the gymnast attempts to use handstand support or swing skills on the apparatus.

X-rays can show reactive changes in the developing epiphysis of the proximal humerus. Radiographic studies may show a separation of developed bone in the acromion, termed os acromiale. The deltoid muscle attaches to the acromion, which is important for the support of the shoulder joint. If the os acromiale is symptomatic (i.e., pain is persistent), surgery is considered to repair the injury. An MRI scan is usually done to accurately diagnose the reasons for instability and stress reactions at the growth center of the humerus.

Most injuries to the arm and shoulder girdle respond to activity modification and rest, followed by reconditioning exercises directed at strengthening the upper extremity and core muscles. Medical intervention is often required to accurately diagnose, manage, and correct potential problems that affect athletic performance.

Spine

The primary support structure for the gymnast is the vertebrae and muscles of the spine. The vertebrae and muscles enable the gymnast to do acrobatic movements that propel the body through balanced and moving positions while tumbling and performing on the apparatus. The stacks of bony elements that make up the cervical, thoracic, and lumbar spine and the disks made of durable gel-like cushions that rest between each individual vertebra, as well as the interconnecting ligaments, muscles, and tendons, are all vulnerable to injury. Large compressive loads along the length of the spine are magnified by tortional shear forces when the body is flexed forward and backward, as well as while executing twisting skills on the floor and beam and when dismounting from the apparatus.

Many gymnastic movements position the spine in hyperextension; apparatus work exposes the spine to torsion against resistance. Powerful and explosive compressive forces expose the spine to catastrophic injuries from falls. The most severe injury to the spine is a cervical spine fracture that results in paralysis. A stress fracture, called *spondylolysis*, is a moderately severe injury to the vertebrae of the lower spine.

The skeletally immature spine is especially at risk for growth plate fractures. Ruptures or the degeneration and inflammation of the disks and the ligaments that support the spine can be the cause of a moderate degree of pain so persistent that the gymnast can no longer train. Moderate and minor strains are caused from long and demanding training schedules that may progress in severity over time. Muscle and tendon strains at their attachments to the spine are the most common injuries to this region.

Painful symptoms from lower spine injuries may be localized to the lower back or may radiate to the buttock or lower leg. When simple treatment measures fail to relieve symptoms, an X-ray, a bone or computed tomography (CT) scan, or an MRI scan can be used to accurately identify the cause. Effective treatment measures for the most disabling pain symptoms include injecting steroids with a local anesthetic near the disk, the nerve, or the small joints of the spine.

Removing provocative skills from training regimens, decreasing the volume of training, and using physical therapy to relieve pain and recondition core muscles are all measures used to treat the most common spine injuries. The use of a brace can also aid in the healing process, as it can be effective in supporting a proper body position of the spine. Improving the gymnast's training environment to more softly cushion dismounts and tumbling routines with matted surfaces promotes injury prevention.

Lower Extremity

The gymnast's lower extremity joints, such as the knee, the ankle, and the foot bones, are exposed to extreme forces during tumbling and vaulting maneuvers and while performing dismounts from the apparatus. Female gymnasts compete in three of four events. These events—floor exercise, vault, and beam—depend on the lower extremity and explain why there is a greater frequency of trauma recorded to this part of the body in gymnastic injury surveillance studies. The ankle joint, in particular, is prone to sprains. The knee and foot experience injuries to ligament structure, cartilage tears, and fractures to growth centers and developed bone.

Knee

The gymnast, when performing tumbling exercises on the floor, quickly accelerates with a rebounding movement, twisting, changing direction, and finishing, using a combination of acrobatic skills, with a sudden declarative stop at the end of a tumbling sequence. Tumbling surfaces are made of spring flooring to improve the gymnast's ability to increase vertical height, from which advanced skills, such as multiple somersaults, with or without twisting elements, are completed. The types of injuries can be better understood by considering these factors and by considering the increasing difficulty of skills performed by the elite gymnast.

Technical mishaps leading to injury can occur when tumbling on the floor or beam and when dismounting or landing from a vault. The most common serious injury seen is a torn anterior cruciate ligament (ACL). Twisting and high-compression loads cause cartilage tears inside the knee joint between the surfaces of the end of the thighbone, the femur and the tibia, or the shinbone. Injury to these half-moon and cushion-like cartilage structures, called the *meniscus*, and to the cartilage covering the ends of these bones can cause pain, swelling, and stiffness, limiting the athlete's ability to run, leap, jump, or land from dismounts.

Disorders of the kneecap that irritate the cartilage covering on its underside can also lead to disabling symptoms, making it difficult to run or land while executing gymnastic skills. An example of this would be when the patella is not moving along a symmetrical path or is not stable when moving. Both MRI and X-ray studies accurately diagnose these disorders of the knee joint. The majority of these injuries of the knee joint and patella benefit from arthroscopic surgery.

Lower Leg

During gymnastic routines, the ankle and foot are exposed to repetitive loads with frequent punching and torsion movements that propel the body through complex somersaulting that is often combined with rebounding and twisting movements. For such a small area, much like the wrist and hand, a remarkable variety of acute and overuse injuries can occur.

Injuries arise from the rapid accelerating and decelerating forces the gymnast places on the bone and muscle and tendon structures and the joint's ligament and cartilage tissues. Acute injury is usually related to dismounting from the apparatus, technical mishaps, and overtraining.

Because of the rigorous demands of gymnastic training and the effect of normal variations in growth and development, the athlete is exposed to stress injuries that develop slowly over time. For instance, an athlete with increased laxity of the connecting ligaments between the large and small joints is more prone to strains, leading to irritation of the tendon attachments around the joints of the ankle and foot and an increased risk of tears to the supporting ligaments. In the gymnast with relaxed or flat feet, painful stress reactions are felt along the bones forming the arch of the foot and the tendons traveling around the ankle and attaching to the middle and end of the foot.

Overtraining in the female gymnast with a flat, or pronating, foot can also lead to irritation along the front of the tibia from repetitive muscular contractions, called *shin splints*. This problem can be distinguished from stress fractures through radiological studies, including MRI or bone scans. Bracing, taping, and orthotic supports are used to improve ankle and foot alignment for these painful disorders.

Ankle

Gymnasts of all ages can experience injuries related to the Achilles tendon. These injuries result from the power generated through the gastrocnemius and soleus muscles, which form the calf. Their mechanism of action—pushing the foot downward—can injure the physis at the tendon attachment to the calcaneus, which is the prominent heel bone at the base of the foot. In the younger athlete, this is commonly referred to as *Sever disease*. Complete detachment of the tendon and bone can happen through the calcaneus's growth center during periods of rapid growth. In the skeletally mature athlete, rupture of the tendon structure can occur when tumbling, as the gymnast punches his or her feet against the flooring. Surgery is necessary to restore tendon continuity when a rupture or fracture occurs.

Ankle sprains are the most common injury in gymnastics. They are the result of an imbalanced load placing the foot in an inverted position, rupturing the ligaments on the outside of the ankle. The ankle becomes swollen, painful, and weak to weight bearing and is treated by physical therapy methods, along with taping, bracing, and pain-relieving medications, to restore mobility and strength. A recurring injury is disabling and requires surgical restoration, with repair or replacement with tendon grafts of the torn structure.

Ankle joint injury is common during impact from landing while tumbling, vaulting, and dismounting. The ankle when landing, a gymnastic skill, experiences estimates of forces 5 to 17.5 times greater than the gymnast's body weight. A less than full rotation from somersaulting can force the ankle bones and cartilage to absorb these forces, compressing their opposing surfaces at extreme angles. Fractures of cartilage, cartilage with bone attachments, and bone and stress fractures in the ankle joint are the disabling injuries recorded by gymnastic surveillance studies. Radiographs, CAT (computerized axial tomography) scans, and MRI scans are used to evaluate this form of injury. These acute fractures can be seen in gymnasts of all age-groups.

Chronic pain may be due to stress fractures or to small areas of injured cartilage and adjacent bone inside the ankle joint, called *osteochondritis*. The rounded surface of the talus is the most common site of this problem. A separation of an osteochondritic lesion leads to pain on weight bearing. The bone involved within the lesion and the cartilage covering it can become loose inside the ankle joint. Repeated injury to the ankle cartilage surface and incomplete healing from sprains can chronically inflame the ankle joint cavity and its lining, called *synovium,* and it may be a source of persistent pain.

Stress fractures are generally treated by an extended period of activity restriction. Sometimes bone healing is enhanced by the use of bone growth stimulation by electrical current, or ultrasound stimulation. Arthroscopic surgery is useful for chronic pain problems of the ankle joint. Arthroscopy can correct loose cartilage and bone structure and inflamed synovium found inside the ankle joint.

Tendons that cross the ankle on their way to their insertion sites on the front and back of the midfoot and forefoot can be irritated by overtraining. The attachment sites can become inflamed from placing the foot in a balanced position that generates and absorbs impact forces from the ball of the forefoot. These tendinitis disorders can be treated by exercise restriction, taping, and the use of orthotic inserts placed inside athletic slippers to balance foot positions. Use of these methods can also help in reducing pain symptoms.

Stress fractures and fractures are seen in a variety of locations in the developing and mature bones of the midfoot and the long bones of the forefoot, called *metatarsals*. Separation of the ephysis, or displaced growth centers, due to a fracture requires surgery. During surgery, the broken structure can be placed in its normal position, which will prevent further disability from growth disturbance and poor alignment.

Prevention

The numbers and types of injuries seen in gymnastics are related to age, growth, and development; skill level (i.e., club vs. elite); environment (training vs. competition); gender as it is related to the region of the body frequently involved; and period of skeletal growth. Risk, severity, and onset of injury, whether acute or chronic, are a function of training intensity, environment or venue, body structure and skeletal maturation, and increasingly difficult skill levels. The region of the body exposed to trauma is determined by the gymnastic skills practiced in training or executed in competition and by the types of events and dismounts.

Precautions and measures taken to reduce injury to bone and joint structures include the use of braces and tape to support and strap a joint, or region of the body, to prevent extremes of movement and the use of protected matting on floor surfaces for dismounts and when practicing landing and tumbling and vaulting skills. Progression to more advanced skill levels should be planned in concert with exercises designed to improve both strength and flexibility, by targeting the muscles surrounding the pelvic and shoulder girdles and core muscle groups and by way of proprioceptive training through developing muscular reflexes to coordinate the stabilizing joint motion.

Strategic planning should be used proactively in gymnastic training to allow for a variation of event selection so that the extremities are protected from overloading. This can be achieved by controlling the frequency and intensity of repetitive loads on the muscles and skeleton. Recognizing the symptoms that are characteristic of overuse, along with activity modification, can help limit the complications associated with injuries that are particularly severe during periods of rapid growth.

Having a coaching qualification and a certification in safety that provides instruction on physical preparedness, spotting techniques, training strategy, and environment is important to injury prevention. The evaluation of competition rules and the performance environment has led to important changes designed to minimize injury frequency and risk linked to competition.

William A. Mitchell Jr.

See also Ankle Sprain; Elbow and Forearm Injuries; Overtraining; Spondylolysis and Spondylolisthesis; Stress Fractures; Wrist Injuries

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H

Hammertoe

Hammertoe is a deformity of the second, third, or fourth toe in which the tip of the toe is bent downward at the middle joint (known as the *proximal interphalangeal*, or PIP, joint), and the middle of the toe is cocked upward, resembling a hammer. It is strongly associated with hyperextension of the *metatarsophalangeal* (MTP) *joint* (where the base of the toe attaches to the rest of the foot), as well as having a longer second toe than the first. Hammertoe deformity can be either flexible or fixed. Initially, the toe maintains flexibility. Flexible deformities allow the examiner to manipulate the toe and move the affected joint back into a neutral position. However, over time, the tendons may tighten and can become permanently stiff. Fixed deformities, such as these, do not allow repositioning. Rather, they are corrected with surgery. Hammertoe is approximately five times more common in women.

Causes

The most common cause of hammertoe is the long-term use of poorly fitting shoes. Shoes that narrow toward the toes, have high heels, and are too small are the common culprits. Shoes that narrow toward the toes cause crowding of the smaller toes and push them into a flexed (bent) position. The condition can be aggravated by the feet rubbing against the small toe box, and this can lead to the formation of corns and calluses. High-heeled shoes increase the pressure placed on the ball of the foot and the toes. They force the toes down against the narrow toe box and increase the bend in the toe. With long-term use, the toe muscles weaken and lose the ability to straighten the toe. Risk of hammertoe also exists in children who continue to wear shoes that they have outgrown. The toes pay the price when a foot is squeezed into a shoe that is too small. Deformities can occur at both the interphalangeal joints (the joints in the toe) and the MTP joint.

While the majority of cases are attributed to poorly fitting footwear, a combination of other factors can also increase the risk of acquiring hammertoe. Anatomical problems such as a long second toe, bunions (hallux valgus), MTP joint instability, and previous toe trauma warrant attention.

- A long second toe causes shoes to fit improperly, because the toe is forced into a bent position (flexion) to accommodate the shoe. An abnormal motion of the second toe triggers excessive motion of the MTP joint, and this can lead to MTP synovitis (irritation of the joint capsule where the base of the toe connects to the foot). The joint support structures (i.e., muscles, tendons, and ligaments) weaken with abnormal motion, increasing the risk of MTP joint instability. Patients often complain of a lump at the ball of their foot and pain at the top of their foot near the base of the toes.
- Bunions present with an angulation of the big toe. The resultant pressure placed on the second toe can cause abnormal positioning and bending

of the second toe, particularly while compressed into shoes.

- Prior trauma to a toe—such as a sprain, strain, fracture (broken bone), or dislocation—increases the risk of abnormal toe anatomy and the resultant positioning problems.

Medical conditions can also increase the risk of developing hammertoe. Studies have shown an association with connective tissue disorders, neuromuscular disease, degenerative disk disease, inflammatory joint diseases, and diabetes. Rheumatoid arthritis causes hammertoe deformity by progressive destruction of the MTP joint, leading to joint instability. Diabetics with peripheral neuropathy are prone to hammertoe because chronic nerve and muscle damage to the foot result in abnormal foot mechanics.

Clinical Findings

Hammertoe can be diagnosed solely from a physical exam. A proper examination includes a neurovascular evaluation, a sensory evaluation, and an evaluation of muscle bulk. The second toe is most commonly involved. Typically, only one or two toes are affected. In the rare case in which all the toes seem to be involved, a thorough neurological assessment is necessary to evaluate for nerve or spinal cord problems (Figure 1).

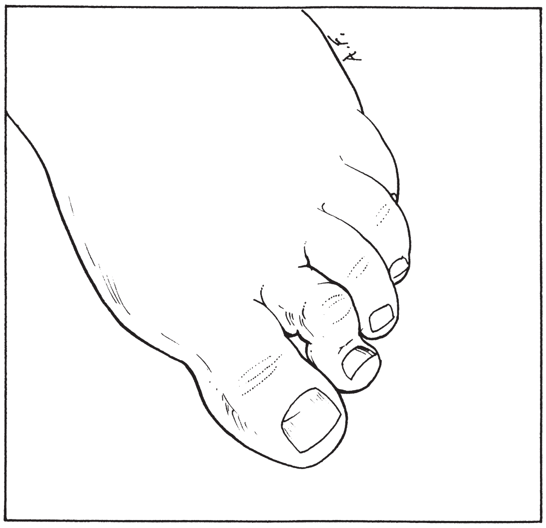

Figure 1 Hammertoe

Note: In hammertoe, usually the second toe, or sometimes another lesser toe, develops a C-shaped deformity.

Hammertoe affects the middle joint of the toe; it is in the bent position. The distal joint (closest to the toenail) does not have a deformity. The foot should be examined in both positions, while standing and while seated. It is important to evaluate the flexibility of the toe; the clinician will move each of the joints and look for dislocations or instability. Hammertoe is amplified by weight bearing.

There are three areas of the foot affected by hammertoe that tend to be painful. The skin on top of the middle toe joint (the dorsal surface of the PIP joint) can become painful due to the development of a hard corn. This is caused by the chronic friction and pressure due to the toe buckling and the skin rubbing against the inside of a shoe. A painful callus can also develop at the end of the toe, just below the tip of the toenail. This is referred to as an end corn. Bending of the toe joint closest to the toenail (the distal interphalangeal joint) causes the tip of the toe to press into the bottom of the shoe. The ball of the foot can also be painful due to the deformities of hammertoe. If the toe bone (proximal phalanx) that connects to the rest of the foot partially dislocates (subluxates) or becomes completely dislocated from the joint, chronic stress on the sole of the foot can trigger the formation of a painful callus. This type of callus is also known as intractable plantar keratosis. Pain at this location is called metatarsalgia.

Pain at any of these locations warrants close evaluation and monitoring. In patients with decreased sensation in the feet, such as diabetics or patients with myelomeningocele, there is a risk of ulceration and infection at these pressure points.

Additional Testing

Further testing is typically not necessary as hammertoe can be diagnosed clinically. However, radiographs may be done to evaluate the deformities. A lateral view is best for looking at hammertoe specifically. An anterior-posterior view of the foot is best for analyzing the dislocation of the MTP joint. Radiographs are routinely done prior to cases needing surgical intervention. Blood testing is done when underlying medical issues are suspected—for example, to rule out rheumatoid arthritis or other inflammatory conditions. There are no lab tests that diagnose hammertoe.

Conservative Treatment

A variety of nonoperative treatment options exists for hammertoe. The goal is to address the condition early in order to have the best results. Options include padding, strapping, taping, changing footwear, exercises, and manipulations.

Padding, strapping, and taping are helpful for reducing the degree of deformity and for relieving pressure over painful joints. Foam or viscoelastic padding is placed over the hammertoe or at the tip of the toe to prevent friction with shoes and corn/callus development. Tube gauze (e.g., a sleeve that slips over the toe) and toe caps are also used. Soft shoe insoles and arch pads are recommended in cases of intractable plantar keratosis to help redistribute weight away from the painful areas. Tape and toe slings are used to promote correct toe positions. They are carefully placed to keep the MTP joint in a slight plantarflexion (as in pointing the toes). The middle toe joint (PIP) compensates by straightening out.

Proper footwear is critical in reducing pain and progressive deformity. Recommendations include shoes with a low heel and a large toe box. Tight, narrow, and high-heeled shoes should be avoided. It is best to buy shoes that are half an inch longer than your longest toe. This reduces the chance of the toes buckling in the toe box. Shoes can be adjusted to accommodate the hammertoe; the toe box can be stretched so that it bulges around the toe, reducing the risk of contact at the top of the shoe.

Stretching and strengthening the toe muscles help correct muscle imbalance and instability. Exercises can be as simple as using the toes to pick up objects off the floor. Another suggestion is placing a towel flat on the floor and, while seated, using the toes to crumple it. Gentle stretching should be done daily. It is recommended that stretching be combined with manipulations—putting the toe in the correct position and taping it securely in place. Recurrence of the hammertoe is likely when stretching and daily manipulation/taping are discontinued.

Surgical Treatment

The most definitive treatment for hammertoe is surgery. Surgery is indicated when conservative therapies have failed and pain becomes disabling. There is a range of surgical options, and the choice is based on the type and severity of the deformity. Flexible deformities are treated with flexor tenotomy (also known as tendon lengthening or tendon release) or flexor-to-extensor tendon transfer. Tendon transfer involves repositioning of the tendon to straighten the toe.

Rigid deformities are treated with arthroplasty of the middle toe joint. Arthroplasty involves the removal of some bone and cartilage to remodel the joint and correct the deformity. The goal is to shorten the toe in order to relieve pressure, alleviate pain, and ultimately straighten the toe. In more severe cases, additional procedures may be necessary. These include reconstruction of the surrounding tendons and ligaments, joint fusion (arthrodesis), fixing a rotational abnormality (derotation arthroplasty), and metatarsal shortening. In cases of concurrent MTP joint instability or abnormality, hammertoe surgery should also include correction of the MTP to prevent a recurrence of the deformity.

Arthrodesis is a fusion of two bones. In cases of hammertoe, this is typically a fusion of the proximal and middle phalanges—the bones on either side of the middle toe joint. The bones are fixed together with a removable pin; they eventually fuse together.

Derotation arthroplasty is another technique for realigning a hammertoe. The surgeon removes a small wedge of skin and straightens the toe by rotating it into the correct position. In some cases, a small section of bone needs to be removed and/or tendons and ligaments need to be remodeled to correct a rotated toe.

Complications from surgery include infection, delayed wound healing, neurovascular injury, numbness, pain, and recurrent deformity.

- Infections may be superficial or deep at the surgical site. If there is an infection around the fixator pin, the pin should be removed and the patient should be treated with antibiotics for 10 to 14 days.
- Good peripheral blood supply is critical for proper wound healing. Physicians evaluate the patient's vascular status when considering surgical intervention. Patients with poor blood flow to the extremities—such as smokers, diabetics, and those with peripheral vascular disease—are poor surgical candidates due to an increased risk for delayed wound healing.

- Neurovascular injury is rare. When it occurs, it is typically seen in patients who have had severe, chronic deformities and more complicated surgical repairs. Manipulation of the nerves and blood vessels of the foot during surgery can irritate these structures, resulting in spasm of the vessels, numbness, or nerve pain. Decreased sensation and numbness are more common than heightened sensation (hyperesthesia). Hyperesthesia can be disabling as these patients are exquisitely tender to painful stimuli.
- Last, surgery is not always 100% effective. If the surgeon is unable to completely correct the deformity or if patients do not follow postoperative instructions (e.g., wearing appropriate footwear), the deformity can recur. Revision surgeries are not as reliable as initial repairs.

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Hamstring Strain

Hamstring injuries are among the most common muscle strain injuries in all sports and exercise. A prior hamstring injury is the biggest risk factor. The goals of treatment are maximizing comfort and restoring function. Early recognition and optimal management are key to having the best possible outcome following a hamstring injury.

Functional Anatomy

Muscles connect different parts of the body, typically bones on either side of a joint, and when they contract (get shorter), they displace or move a joint. In moving joints, muscle groups have other muscle groups that either support or oppose the specific plane of movement (the agonist group or the antagonist group). *Concentric movement* occurs when a muscle group contracts and shortens to perform its main function—for example, the hamstring bending the knee. *Eccentric movement* occurs when a muscle contracts during the antagonistic function—for example, the hamstring restraining knee extension during sprinting; the muscle contracts but does not necessarily shorten in length, and in fact, it may be forced to lengthen by the opposing muscle group.

This concentric-eccentric relationship is important to understand the mechanism of injury involving the hamstring muscle group. The hamstrings include the biceps femoris, the semitendinous, and the semimembranous muscles. The three muscles originate at the ischial tuberosity, and the distal insertions vary based on the muscle. The biceps femoris attaches distally on the tibial lateral condyle and fibula head, the semitendinous attaches on the proximal medial tibia, and the semimembranous attaches in the medial tibial condyle pes anserine region. Like most muscle groups in the human body, the hamstring muscle group works by pulling the insertion toward the origin, so its function is to flex (or bend) the knee (bringing the heel toward the buttocks) and assist in the extension of the hip (moving the leg to the rear).

Mechanism of Injury and Risk Factors

The majority of hamstring injuries in sports occur in velocity athletes (e.g., sprinters, running backs, wide receivers, soccer and basketball players) and result because of an excessive eccentric force during the lengthening of the muscle—especially when running, sprinting, or coming to a sudden stop (deceleration). Hamstring injuries can occur when the muscle is contracting at the same time when other forces are causing the muscle group to lengthen, such as in sprinting and stopping suddenly. Mechanically, hamstring injuries occur frequently at the later part of the swing phase, when the hamstring contracts eccentrically to decelerate knee extension in preparation for foot strike. Another common mechanism of hamstring injury is during the stance phase, when the hamstrings contract in a concentric fashion to assist in hip extension.

An important risk factor for an acute hamstring injury is a past history of the same injury. Other proposed risk factors include a muscle imbalance or weakness of the hamstrings, poor flexibility, inadequate warm-up, muscle fatigue, and overtraining. Many recurrent or chronic hamstring injuries may, in part, be due to a less than optimal rehabilitation of the first initial injury (Figure 1).

Classification

The hamstring injury can occur at any location in the muscle (in the origin, insertion, or muscle belly). The traditional classification is based on the degree of muscle fiber injury. A first-degree strain signifies only minimal structural injury to the muscle fiber and results in minimal strength loss and almost no functional disability. A second-degree strain signifies a partial tear of the muscle, macrotrauma, and the athlete may have loss of strength and some function. A third-degree strain represents a complete rupture of the muscle and is associated with significant functional disability and often significant discomfort. When a third-degree injury to the hamstring occurs at its proximal origin, it may be accompanied by an actual avulsion fracture (bone fragment separation) of the ischial tuberosity.

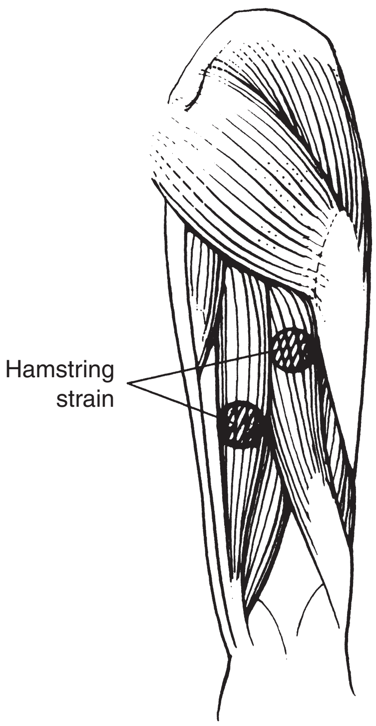

Figure 1 Hamstring Strain

Notes: Hamstring strain—a stretch, tear, or complete rupture of one or more of the three muscles in the posterior of the thigh—is one of the most common injuries in sports. The likelihood of injury is dramatically increased if the muscles are not sufficiently warmed up.

Treatment

The healing process in muscle strains involves three phases: the acute, subacute, and chronic remodeling phases. The first two involve the production and laying down of the connective tissue scar, and the third phase involves the attempted regeneration and remodeling of the affected musculotendinous structure.

After the immediate injury, there may be bleeding and/or fluid extravasation (the leaking of fluid and materials out of the blood vessels into the surrounding tissue). Inflammatory cells migrate to the area of injury and begin the process of cleaning up, scarring, and healing. The subacute phase continues the fibrous scar tissue formation. The chronic remodeling phase is the body's attempt to turn the scar tissue back into an organized muscle and tendon fibrous structure. After a second- or third-degree hamstring injury, the tissues of the injured area may never look completely the same under a microscope; fortunately, however, the clinical goal of restoring and maximizing function can often be achieved with timely and appropriate management.

During the acute phase, the approach to muscle strain treatment includes the mnemonic PRICES (*p*rotection, *r*est, *i*ce, *c*ompression, *e*levation, and *s*upport). Ice, compression, and elevation should be applied for 48 to 72 hours at least to help reduce pain and swelling; anti-inflammatory medicines such as ibuprofen or naproxen are commonly used as well. The rationale in this phase is to limit the amount of bleeding and inflammation to the point of comfort while, at the same time, permitting the healing process to start.

Once the acute phase is over and the athlete is more comfortable, the rehabilitative phase may start, and this can include several aspects, such as tissue mobilization, stretching, strengthening, balance training, and cross-training. Early mobilization allows for alignment of the regenerating muscle fibers, resorption of the connective tissue scar, and decrease in muscle atrophy. Mobilization includes a combination of stretching and strengthening exercises that should be relatively painfree to avoid further injury. The strengthening process can start with concentric contractions, progressing to eccentric conditioning.

If the athlete has significant or increasing pain, the intensity of the program should be decreased. If the athlete tries to return too soon to full activity, more damage and inflammation could occur. Cross-training activities may include stationary bicycling and swimming to help in rehabilitation and maintain cardiovascular conditioning.

The length of time for maximal recovery will vary from days to weeks for a mild, first-degree strain to months to a year or more for a third-degree, complete tear. Eccentric strengthening is the foundation of the latter stages of hamstring rehabilitation. Other therapeutic modalities including moist heat, ultrasound, electrical stimulation, deep friction massage, myofascial release, and neuromobilization have been recommended in treating hamstring injuries. Once the athlete has recovered normal strength and flexibility, he or she can start to jog at low intensity and progress as tolerated, avoiding painful activities. If pain recurs, the intensity of the program may be decreased before attempting to advance again. More advance rehabilitation exercises for the athlete may incorporate activities such as polymetrics (jumping or bounding) and neuromuscular proprioception (combining strength and balance). The rehabilitation program should be individually tailored to the patient's needs and functional expectations.

Most hamstring injuries can be treated nonoperatively and will have good outcomes with appropriate management. Surgery may be considered for a complete hamstring tear near the origin or distal insertion based on the patient's pre-injury function level and the postinjury functional expectation. Surgery could also be considered in cases of bony avulsion fractures with more than 2 centimeters (cm) of displacement; displacements of less than 2 cm heal adequately with the nonoperative approach described above in the normal, nonelite athlete.

Conclusion

In summary, hamstring injuries are common and could have significant consequences if they are missed or less than optimally managed. They are more often seen in sprinting athletes and those involved in sports with sudden starts and stops. A prior hamstring injury is the most common risk factor, and optimal rehabilitation is essential for these athletes. The key for hamstring injury treatment is early recognition of the injury, initiating the PRICES protocol promptly, and following with appropriately aggressive and optimal rehabilitation. Eccentric strengthening is the foundation for a successful rehabilitation program, and it should be started once the athlete is painfree and comfortable with concentric exercises.

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Hand and Finger Injuries

Hand and finger injuries are extremely common in sports, particularly in rock climbing and ball-handling sports, such as basketball, football, softball, and volleyball. Hand and finger injuries are also common in boxing, snowboarding, skiing, and skateboarding. Injury rates vary from 15% to 65% of all injuries, depending on the sport involved. Injury patterns are sport specific, depending on the demands placed on the upper extremity. Both acute traumatic injuries and chronic overuse injuries are seen.

The majority of these injuries require minimal intervention. However, some are potentially serious, requiring immobilization, precise splinting, or surgery. Athletes often neglect these injuries, expecting them to resolve spontaneously, and they may present too late for effective treatment. Early assessment and management of hand and finger injuries is very important to avoid long-term deformity and functional impairment.

Hand and finger injuries are more common in younger populations than in adults. This is due, in part, to increased sports participation, particularly in extreme sports, by younger athletes. Other factors include the use of age- or size-inappropriate equipment, not wearing appropriate safety equipment, and poor supervision, coaching, and/or technique. Sprains are the most common injuries, accounting for 20% to 50% of all injuries, followed by contusions (15%–30%) and fractures (5%–35%). Fractures of the fingers are among the most common sports-related injuries. Hand fractures occur most often in the bones of the distal fingers (phalanges) (about 50%), followed by the metacarpals (30%–35%), proximal phalanges (15%–20%), and middle phalanges (8%–12%). Approximately one third of hand fractures are intraarticular (into the joint).

Anatomy

There are 27 bones in the hand and fingers. The fingers comprise the distal, middle, and proximal phalanges, whereas the thumb has a distal phalanx and a proximal phalanx. There are five metacarpal bones and eight carpal bones (capitate, hamate, triquetrum, lunate, scaphoid, trapezius, trapezoid, and pisiform). The scaphoid bone can be palpated at the base of the thumb in the so-called anatomical snuffbox. The floor of the anatomical snuffbox comprises the carpometacarpal joint of the thumb. The physes or growth plates of the phalanges are located proximally and close typically between 14 and 16 years of age. The physes of the metacarpals, with the exception of the thumb, are located distally in the metacarpal neck area. The physis of the thumb metacarpal is located proximally, near the carpo-metacarpal joint (Figure 1).

Joint stability in the hand and fingers is conferred by the ligaments. Collateral ligaments at the interphalangeal joints prevent excessive radial and ulnar deviation. The collaterals insert broadly on both the epiphysis and the metaphysis of the phalanges. At the metacarpophalangeal (MCP) joints, the collateral ligaments insert on the epiphysis of the more distal phalanx, making Salter-Harris III avulsion-type fractures in children and adolescents much more common at the MCP joint level. Another structure offering stability to the phalangeal joint is the volar plate, a thick fibrocartilagenous tissue found on the palmar or volar surface of the phalangeal joint. This is a common site of injury in the fingers.

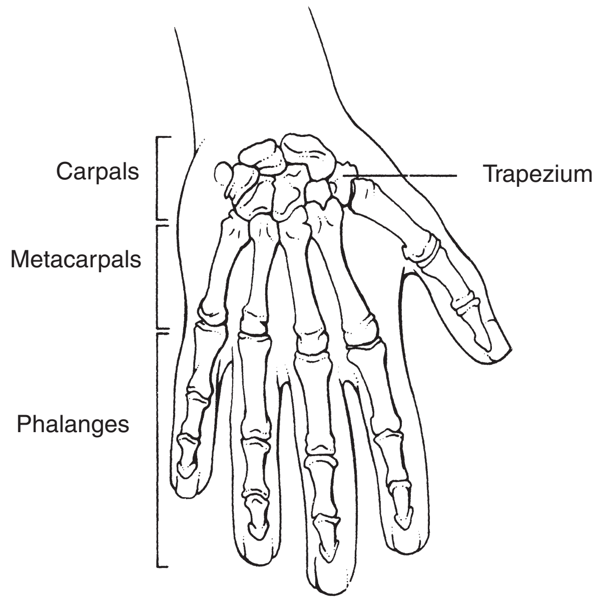

Figure 1 Hand and Finger Anatomy

There are several extrinsic tendons traversing the hand. These include the long thumb abductor (abductor pollicis longus), the thumb flexor and extensors (the flexor pollicis longus, extensor pollicis longus, and extensor pollicis brevis), the extrinsic digital extensors (the extensor digitorum comminus, extensor indicis proprius, and extensor digiti quinti), and the extrinsic digital flexors (the flexor digitorum profundus and the superficialis). In addition, there are 18 intrinsic muscles of the hand, including the thenar, hypothenar, lumbrical, interossei, and adductor pollicis muscles.

Evaluation of Injuries

Details of Injury

When an athlete presents with an injury to the hands or fingers, certain factors, such as hand dominance, sport(s) played, position played, and level of performance, may affect how the injury is managed. Determining the mechanism of injury, specifically the position of the hand or fingers, the direction and magnitude of the applied force, and the symptoms the athlete is experiencing (pain, weakness, and instability), is essential to help make a diagnosis. Athletes should be asked about initial management of the injury, including whether any manipulation or reduction maneuvers were performed and how the hand/finger was splinted. More serious injuries usually prevent an athlete from continuing with his or her sport, secondary to pain and loss of function.

Physical Findings

Injuries to the hands and fingers may result in swelling, bruising, lacerations, abrasions, wounds, or obvious deformities. There may be tenderness to palpation. Reproducible bony tenderness usually indicates a fracture. Tenderness to palpation in the anatomical snuffbox may indicate a scaphoid fracture.

Movement of the fingers and hand may be affected by injuries. Active range of motion of fingers includes flexion, extension, abduction, and adduction. Active range of motion of the thumb includes flexion, extension, palmar abduction, and adduction, as well as opposition (from the thumb to the fifth digit). Normal range of motion of the second through fifth digits is about 80° of flexion at the distal interphalangeal (DIP) joint, 100° of flexion at the proximal phalangeal (PIP) joint, and 90° of flexion at the MCP joint. In addition, there may be damage to the nerves of the blood vessels in the hand or fingers.

A bony or joint injury may cause an angular or rotational deformity of the finger or hand. The principle of tenodesis can help identify abnormalities associated with hand and finger injuries. Passive wrist extension in the normal hand and wrist results in obligate passive digital flexion, with all the fingers roughly parallel. In the presence of a rotational deformity, the affected digit will overlap or underlap the adjacent fingers. In the presence of a flexor tendon injury, the affected digit will not passively flex with the adjacent digits in the resting position or with passive wrist extension.

Resisted movements can test tendon integrity in each finger. The flexor digitorum profundus is tested by having the patient flex the DIP joint with the PIP joint held in extension. The flexor digitorum superficialis is tested by having the patient flex the PIP joint with the DIP joint held in extension. The extensor tendon is tested by having the patient extend the PIP joint with the MCP joint in extension. In addition, the ulnar collateral ligament of the thumb should be tested by applying radial and ulnar deviations to the thumb with the MCP in 10° of flexion.

Investigations

Any possible bone or joint injury of the hand or fingers should be evaluated with X-rays. Routine views include posterior-anterior (PA), lateral, and oblique views. Oblique X-rays will often identify bony injuries not apparent on anteroposterior (AP) or lateral views. Magnetic resonance imaging (MRI) or computed tomography (CT) may be useful in cases of suspected carpal, articular, or ligamentous injuries.

Types of Injury

Table 1 provides the different types of hand and finger injuries.

Table 1 Hand and Finger Injuries

Common	*Uncommon*
Metacarpal fractures	Bennett fracture
Phalangeal fractures	MCP joint dislocation
PIP joint dislocations	DIP joint dislocation
Ulnar collateral ligament sprain/tear (gamekeeper's thumb)	Sprain of DIP joint
	Mallet finger
Laceration	
Jersey finger	
Subungual hematoma	
Sprain of PIP joint	
Flexor/extensor tendinitis	

Note: DIP = distal interphalangeal joint; MCP = metacarpophalangeal joint; PIP = proximal phalangeal joint.

Prevention of Injury

Many hand and finger injuries can be prevented. Appropriate equipment should be worn for the particular sport being played. In younger athletes, age- and size-appropriate equipment should be used.

Return to Sports

Return-to-play recommendations following hand and finger injuries vary according to the type of injury, the treatment plan, the level of acuity or chronicity, and the sport-specific demands of the athlete. There are no universal guidelines; however, certain principles should be applied. Bony or ligamentous injuries generally take 3 to 6 weeks to heal. Injuries should be appropriately immobilized in a cast or splint to allow participation in activities. Full, unprotected return to sports should not take place until the athlete has recovered full, active and passive, painfree range of motion, as well as almost full strength, of the injured hand/finger. Injuries to the hands and fingers have the potential for delayed or failed healing, regardless of treatment, so athletes should be referred early to a hand surgeon for follow-up. Safety of the injured athlete as well as the other sports participants should be of paramount concern. If an athlete intends to return to sport wearing a protective device, coaches, trainers, and officials should be aware of this and should give their approval prior to participation.

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Hand and Finger Injuries, Surgery for

Hand injuries are common in athletes, representing 5% to 15% of orthopedic injuries. While contusions and sprains are the most common, fractures and soft tissue injuries involving the tendons and ligaments of the hand do occur and often require specialized care. Given the importance of hand function in athletics as well as in activities of daily living, timely diagnosis and appropriate care are necessary to expedite return to play and to maximize long-term outcomes. This entry discusses common hand injuries in athletes, with an emphasis on those requiring surgical care.

Clinical Presentation

One of the great challenges in treating hand injuries in athletes is their varied clinical presentation.

In general, sports hand injuries occur from traumatic events during practice or play. Patients will often be able to recall a specific event during which their hand was injured (e.g., falling onto the outstretched hand, axial load on the finger from a ball, and a direct blow onto the hand by another athlete's stick). Understanding the mechanism of injury provides clear insight into the problem.

Clinically, there may be pain, swelling, and bruising. In more extreme situations, there may be wounds, lacerations, or obvious deformities of the hand/fingers. Furthermore, the athlete may report an inability to move the injured part. When athletes present days, weeks, or even months after an injury, the clinical complaints may be different. Pain, clicking, "giving way," and stiffness during athletic activities are common complaints in late-presenting injuries and should alert the care provider to an underlying orthopedic cause.

Physical Examination and Pertinent Anatomy

A thorough physical examination should be performed, based on the athlete's complaints and the care provider's knowledge of the pertinent anatomy. While a comprehensive review of the complex anatomy of the hand is beyond the scope of this entry, a number of important anatomic principles will be presented here as they relate to physical examination.

The examination begins with observation. Inspection for isolated swelling, bruising, wounds, and deformities will give clues as to the underlying problem. Normally, in the resting position, the fingers adopt a slightly flexed posture due to the action of the flexor tendons. In this position, all the digits should be parallel, with no overlap or underlap of one finger over another. If the wrist is passively extended, all the fingers should flex toward the palm. If the fingers do not passively flex in a parallel fashion, suspicion should be raised for a tendon, ligament, or bony injury. This is often referred to as the *tenodesis effect* (see images a and b).

(a) (b)

A patient with abnormal tenodesis

Source: Courtesy of the Children's Orthopaedic Surgery Foundation, Boston, Massachusetts.

Note: (a) All the digits appear aligned with the wrist flexed and (b) passive wrist extension demonstrates abnormal rotation of the ring over the long finger.

After inspection, all the bones and joints of the hand (or affected part) should be palpated. Any reproducible localized tenderness should alert the examiner to a possible bony injury. As each finger (excluding the thumb) has two flexor tendons—one bends the distal interphalangeal joint (DIPJ) and the other bends the proximal interphalangeal joint (PIPJ). Isolated testing should be performed to ensure that the athlete can bend each specific joint in isolation. Ligaments can be assessed by bending, extending, and providing side-to-side stress of the joint in question; as there is great variability in joint laxity and flexibility from individual to individual, comparison with the adjacent finger or the same finger of the uninjured hand is helpful. Finally, joint motion should be assessed actively (i.e., by asking the patient to make a fist and open his or her hand) and passively (i.e., by asking the patient to relax and allowing the examiner to move the finger/hand).

Diagnostic Testing

X-rays should be taken in cases of reproducible localized tenderness, joint stiffness, or deformity. Given the complex shape of the hand and fingers, X-rays of the specific injured part should be taken to obtain more detailed information and avoid missing injuries (e.g., X-rays of the index finger instead of X-rays of the entire hand). In cases where there is a question of specific soft tissue injury (e.g., ligament tear, joint instability, and tendon rupture), magnetic resonance imaging (MRI) can be helpful, though this is not routinely used.

Principles of Treatment

A number of general treatment principles apply to the management of hand injuries in the athlete. In addition to a careful and comprehensive physical examination, an appropriate radiographic imaging—including orthogonal views—of the affected part is imperative. Open wounds or lacerations should be treated with irrigation and wound closure, with the exception of "fight bites," animal bites, and late-presenting wounds. In cases of suspected or known fractures, the hand should be immobilized in *intrinsic plus position* until definitive orthopedic evaluation is obtained. Intrinsic plus position places the wrist in 20° to 30° of extension, the metacarpophalangeal (MCP) joints in 70° flexion, and the interphalangeal joints straight, to avoid soft tissue contractures and subsequent stiffness. Temporary splinting may also be considered for soft tissue injuries without fracture.

While the majority of hand injuries can be managed with nonoperative care, a number of injuries require surgery, including open fractures, intraarticular fractures, flexor tendon ruptures or lacerations, and ulnar collateral ligament tears of the thumb MCP joint. In general, referral to a hand surgeon within 5 to 7 days of injury is desired in cases where surgical treatment is deemed necessary.

Specific Injuries: Bony

Unicondylar Fractures

Unicondylar fractures refer to intraarticular fractures of the phalanges (image c). Typically sustained during "jamming" or "twisting" injuries, these injuries may lead to irregularity of the joint surface, deformity, stiffness, and even arthrosis in the long term. For this reason, surgical treatment is recommended to restore normal joint surface contour and to correct deformity; surgery is even considered in nondisplaced fractures due to the inherent instability of the small fracture fragments seen in this injury.

Phalangeal Shaft Fractures

Fractures of the phalangeal shafts are typically due to bending or twisting forces. Patients will present with pain, swelling, and reproducible tenderness at the fracture site. X-rays will confirm the diagnosis. In cases of excessive angulation or malrotation, surgery can be performed to realign and stabilize the bone to maximize functional outcomes.

(c)

An X-ray demonstrating a unicondylar fracture of the phalanx

Source: Courtesy of the Children's Orthopaedic Surgery Foundation, Boston, Massachusetts.

Volar Plate Avulsion Fractures

In hyperextension injuries to the PIPJ, often the stout volar ligaments will avulse a small portion of the base of the middle phalanx (image d). Although it is technically a fracture, the treatment principles for this injury are more like those for a sprain. Provided that the interphalangeal joint is stable with range of motion, excessive splinting is to be discouraged due to the real risk of long-term stiffness and joint contractures. In these situations, Coban wrapping and buddy taping of the affected finger to an adjacent finger will provide adequate comfort, prevent recurrent injury, and facilitate range of motion.

Boxer's Fractures

Boxer's fractures refer to fractures of the fifth metacarpal neck. Though rarely seen in high-level boxers, these injuries do occur from clenched-fist injuries. Despite the often dramatic appearance on X-rays, healing with up to 40° or more of angulation leads to little functional compromise, owing to the compensatory motion at the MCP and carpometacarpal (CMC) joints. Surgery is only recommended in cases of excessive angulation or malrotation resulting in "scissoring" of the small finger over the ring finger.

(d)

A lateral X-ray of a small volar plate avulsion fracture of the base of the middle phalanx

Source: Courtesy of the Children's Orthopaedic Surgery Foundation, Boston, Massachusetts.

Metacarpal Fractures

Fractures of the metacarpal shafts are common and are due to direct blows or falls onto the hand. Given the supporting soft tissues and adjacent bones, isolated fractures of the central metacarpals are usually stable and heal well with a splint or cast immobilization. Surgery is recommended in cases of open fractures, multiple metacarpal fractures, or fractures with malrotation and/or excessive angulation.

Base-of-Thumb Fractures

Fractures involving the base of the thumb metacarpal have distinct treatment considerations. In general, these fractures may be extra-articular, simple intraarticular, or comminuted. Extra-articular fractures are typically treated with closed reduction and splinting or casting; in cases of excessive instability or malalignment, surgery can be considered to stabilize the injury. Simple intra-articular fractures of the thumb metacarpal base are often referred to as Bennett fractures. These injuries are often quite unstable; percutaneous pin fixation or formal open reduction and internal fixation is often needed to restore the joint surfaces and realign the thumb. Rolando fractures refer to more complex, comminuted fractures of the thumb metacarpal base and are treated with surgical reduction and fixation.

Specific Injuries: Ligamentous

PIPJ Dislocations

Dislocations of the PIPJ are common, and the vast majority are treated with closed reduction, buddy taping, and early range-of-motion exercises. In rare situations where a dislocation is associated with a large avulsion fracture from the base of the middle phalanx, the joint may be persistently unstable. In these situations, surgery is recommended to reduce and stabilize the bony injury in order to keep the joint reduced.

Metacarpophalangeal Joint Dislocations

Metacarpophalangeal dislocations most commonly affect the thumb, index finger, and small finger. The vast majority may be treated by closed reduction, with excellent outcomes. Closed reduction is performed with the wrist flexed (to loosen the tension of the flexor tendons) by first hyperextending the MCP joint, followed by longitudinal traction and a subsequent downward (or palmar) pressure applied to the base of the proximal phalanx. In rare situations, immediate, straight longitudinal traction will cause soft tissue to be interposed into the joint, thus preventing closed reduction. In these situations, surgical reduction is required. In general, careful X-rays of the affected joint, including a true lateral view, are necessary to confirm adequate joint alignment following a closed or open treatment.

Gamekeeper's (or Skier's) Thumb

Gamekeeper's thumb refers to a tear of the ulnar collateral ligament of the thumb MCP joint, often resulting from a twisting injury or fall onto an abducted thumb. Patients will present with pain, swelling, and tenderness over the ulnar aspect of the joint. Instability with stress testing of the thumb, with the joint both in extension and in 30° flexion, will confirm the diagnosis. X-rays are often normal; MRI may assist in confirming the diagnosis but is typically not needed. In complete tears—particularly when there is gross instability in both extension and flexion—the avulsed stump of the ligament may be pulled away from its bony insertion, and soft tissue (the adductor pollicis aponeurosis) may be interposed. In these situations, surgical repair is recommended to provide joint stability and to maximize outcomes.

Specific Injuries: Tendon

Mallet Finger

Mallet finger refers to a disruption of the extensor tendon as it attaches to the distal phalanx—typically the result of an axial load. Patients will present with a "droop" and inability to actively extend the DIPJ. X-rays are taken to ensure that there is no associated bony fracture. Mallet injuries are treated with full-time splinting of the DIPJ in full extension for 6 weeks, leaving the PIPJ free. In cases where there is a large bony avulsion fracture and associated joint instability, surgery may be considered.

Jersey Finger

Jersey finger refers to a closed avulsion of the flexor digitorum profundus tendon from its insertion on the distal phalanx. Most often affecting the ring finger, this condition commonly occurs when an athlete grabs the jersey of another player while he or she is running away. Findings may be subtle, and careful examination for isolated DIPJ flexion is necessary to make the diagnosis. Surgery to reattach the flexor tendon to the bone is recommended within 5 to 7 days for these injuries. In situations where the diagnosis is not made acutely or treatment is delayed, multiple surgical procedures may be necessary, with mixed outcomes.

Flexor Tendon Lacerations

Cuts in the palmar aspect of the fingers or hand may result in flexor tendon lacerations. Careful examination of the digit will demonstrate an extended resting posture of the finger and an inability to actively flex the affected part (image e). Often, there is an associated laceration of the digital artery or nerves. After initial wound irrigation and skin closure, an early hand surgery referral is recommended, as these injuries are best treated surgically within 7 days of injury.

Miscellaneous Injuries

Fight Bites

The term *fight bites* refers to wounds sustained in the dorsum of the hand (the MCP joints) from a clenched-fist blow to the mouth. Despite the innocuous appearance of the wounds, there are a high percentage of cases in which the tooth penetrates the MCP joint(s), resulting in infection and bony or cartilaginous defects. After initial irrigation and appropriate doses of antibiotics, these injuries should be evaluated immediately by a hand surgeon. Surgical exploration and irrigation are recommended acutely, even when signs of infection are not initially present.

(e)

A clinical photograph of a small palmar wound resulting in a flexor tendon laceration

Source: Courtesy of the Children's Orthopaedic Surgery Foundation, Boston, Massachusetts.

Note: Note the extended posture of the affected finger in relationship to the adjacent uninjured digits.

Nail Bed Lacerations

Crushing injuries to the fingertips often cause nail bed lacerations, particularly in the setting of associated distal phalangeal tuft fractures and large subungual hematomas. Treatment typically involves removing the fingernail, cleansing the wound, and repairing the nail bed with sutures. This may be effectively achieved under a local anesthetic in the office or in the emergency department setting.

Fingertip Avulsions

Soft tissue avulsions of the fingertip or "pad" are common, particularly in younger children. In general, soft tissue loss of the fingertip may be successfully treated with local wound care and dressing changes provided no underlying bone is exposed and the area of skin loss is less than 1 square centimeter. In cases of exposed bone or larger areas of involvement, referral to a hand surgeon is advised for consideration of surgical treatment.

Donald S. Bae

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Handlebar Palsy

Bicycle riding is a common recreational activity. While most of the medical community is focused on head protection, and rightly so, there are other injuries that occur as overuse injuries in the more than casual rider. Handlebar palsy is a common result of too much pressure on the lateral (little finger side) side of the hand, which compresses the ulnar nerve and creates a pins-and-needles sensation (paresthesias) in the ulnar one and a half fingers (the little finger and the little finger side of the ring finger).

Anatomy

The relevant anatomy of the ulnar side of the hand (hypothenar eminence) is the Guyon canal. the Guyon canal is bordered by the pisiform bone, the hamate bone, and the ligament that attaches them. The ulnar artery also runs through this same canal. The ulnar nerve provides sensation to the ulnar one and a half fingers and motor function to most of the intrinsic muscles of the hand.

Clinical Evaluation

History

Commonly, a rider will come in complaining of paresthesias in the ulnar nerve distribution of the hand. This often occurs during a long ride initially, but often, it becomes progressively worse and can occur earlier on rides. Some athletes only have symptoms at night. The sensation of pins and needles can linger after the ride from as little as a minute to as long as a few hours. The athlete may also complain of some grip weakness. The rider's mileage and terrain should be considered, looking for any significant changes or increases. Any previous history of trauma to the neck, elbow, or hand is important as well. Any injury to the ulnar nerve along its course can cause similar symptoms. A fall off the bike onto the ulnar side of the hand could fracture the hook of the hamate and could also injure the nerve.

Physical Exam

The evaluation starts with a good cervical spine exam, trying to exclude a cervical disk problem as well as a possible thoracic outlet issue. Following the cervical spine examination, a thorough examination of the elbow and the ulnar nerve as it passes through the cubital tunnel is essential. Finally, an evaluation of the hand and wrist is undertaken. The Tinel test (tapping over the nerve as it runs through The Guyon canal) that is positive (paresthesias) is somewhat indicative of an ulnar neuropathy. Compression sign is also another specific test employed in diagnosing this entity. The examiner places a thumb over the Guyon canal and presses hard enough to blanch the nail bed and holds that compression for about 30 seconds. If this reproduces the paresthesias, it is considered a positive test.

When evaluating a cyclist for an injury, especially an overuse injury, the bike should be examined as much as the athlete. A proper bike fit for the cyclist is paramount for decreasing the risk of overuse injuries. Improper hand position on the handlebars or a too far forward position places too much pressure on the hands. Also, if the rider locks his or her elbows, it can result in too much force being applied to the hands.

Diagnosis

The diagnosis of ulnar neuropathy is mainly a clinical one. If the diagnosis is difficult, then one may start with a plain X-ray to look for a fracture (if there was a trauma). Advanced imaging (i.e., magnetic resonance imaging, MRI) is less helpful in diagnosing ulnar neuropathy unless there is a concern of a ganglion cyst or an ulnar artery aneurysm (both relatively rare entities). The use of electrodiagnostic testing is most common. The use of EMG/NCV (electromyography/nerve conduction velocity) testing can be diagnostic. The examiner must also consider that the paresthesias may be an early sign of an underlying medical condition, such as diabetes or thyroid dysfunction.

Treatment

Nonsurgical

Often, addressing training errors is the most important issue. Rapid increases in the duration, frequency, or intensity of training can increase the risk for any overuse injury. Then one needs to address the rough-terrain riding and how the handlebars are gripped. Teaching the rider to "hold" the handlebars and not to "grip" them is important.

Oral anti-inflammatory medications can be helpful, as well as working with a physical/occupational therapist. A wrist splint is employed to prevent the excessive motion and stretching of the nerve.

Clinicians usually find that the affected hand is the one that does not reach for the water bottle. Therefore, teaching the rider to alternate hands when reaching for the water bottle can be very helpful. Changing grip types and positions often is also helpful.

Bike modifications/changes are also part of the treatment. Doubling the handlebar padding and/or adding gel padding to the riding gloves can remove the pressure. Raising or shortening the stem height can also be of benefit.

Surgical

If the nonsurgical treatments do not resolve the symptoms, then surgical intervention is a viable option. The surgery involves releasing the ligament that extends between the pisiform and hamate bones and that forms the roof of the Guyon canal. Once the ligament is divided, the skin is closed.

Nilesh Shah

See also Ulnar Neuropathy

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Head Injuries

Head injuries are a common occurrence in organized sports and recreational activities, such as hockey, soccer, football, skiing, snowboarding, and cycling. Many sports, such as hockey and football, and recreational activities, such as bicycling, require helmets to prevent head injuries. Head injuries can range from minor contusions, lacerations, and superficial hematomas to more serious conditions including concussions, skull fractures, and intracranial hemorrhages.

Head injuries incurred by participation in sports and recreational activities are responsible for a significant number of visits to emergency departments and physicians' offices each year. More than 10% of all visits to emergency departments are for head injuries, and 3% of all sports-related injuries presenting to emergency departments are head injuries. The majority of sports-related head injuries occur in people under 20 years of age.

Anatomy

The brain is enclosed in the bony skull (cranium). Between the cranium and the brain are three layers of *meninges* (mater). (1) The outer dura mater encloses the venous sinuses. (2) The arachnoid mater bridges the sulci on the cortical surface of the brain. (3) The pia mater is a delicate vascular membrane lining the cerebral cortex. There are also three potential meningeal spaces: (1) the epidural space between the cranium and the dura, (2) the subdural space between the dura and the arachnoid, and (3) the subarachnoid space between the arachnoid and the pia, containing cerebrospinal fluid.

The brain comprises the left and right cerebral hemispheres. The cerebral hemispheres are divided into lobes corresponding to the overlying cranial bones: frontal, parietal, occipital, and temporal. The cerebral cortex is made up of *gyri* (folds) and *sulci* (grooves). The cerebellum and brainstem, consisting of the medulla oblongata, pons, and midbrain, are located posterior and inferior to the cerebral hemispheres.

Evaluation of Injuries

Head injuries can potentially be very serious. Loss of consciousness may indicate a very serious head injury. An unconscious athlete may also have a neck injury and, therefore, should not be moved from the field until the neck has been appropriately immobilized by trained health care personnel. If the airway is compromised or there are signs of neurological deterioration, such as posturing or pupillary abnormalities, the athlete should be intubated and hyperventilated by trained personnel (e.g., a doctor or a paramedic). The athlete should be transported on a spinal board by ambulance to the nearest trauma center immediately (Table 1).

A conscious athlete with a head injury should be removed from the field of play and examined by medical personnel as soon as possible. The athlete should not be left alone and should be frequently reassessed for any signs of deterioration.

Details of Injury

The mechanism of injury may give an indication of the type of injury. Head injuries may result in loss of consciousness, amnesia, or vomiting. Additional symptoms may include headache, nausea, or difficulty concentrating. Athletes may seem

Table 1 Indications for Immediate Transfer to Hospital of an Athlete With a Head Injury

Prolonged loss of consciousness (>5 min)
Decreased level of consciousness (GCS<14)
Increasing headache, nausea
Persistent vomiting
Unstable vital signs
Seizure
Unequal pupils
Focal neurological deficits/evolving neurological signs

Source: Reprinted from Hunte G. Sporting emergencies. In: Brukner P, Khan K, eds. *Clinical Sports Medicine*. 2nd ed. Roseville, New South Wales, Australia: McGraw-Hill; 2001:713–725. With permission from McGraw-Hill Australia.

Note: GCS = Glasgow Coma Scale.

Table 2 Glasgow Coma Scale

Eye Opening	*E*
Spontaneous	4
To speech	3
To pain	2
No response	1
Verbal response	*V*
Alert and oriented	5
Disoriented conversation	4
Speaking but nonsensical	3
Moans or unintelligible sounds	2
No response	1
Motor response	*M*
Follows commands	6
Localizes pain	5
Movement/withdrawal to pain	4
Decorticate flexion	3
Decerebrate extension	2
No response	1
Total score =	*E + V + M*

Source: Teasdale G, Jennett, B. Assessment of coma and impaired consciousness: a practical scale. *Lancet*. 1974;2:81–84. Reprinted with permission from Elsevier.

dazed, irritable, or moody or may have difficulty answering questions.

The athlete's orientation, memory, and concentration may be affected. Orientation can be assessed by asking questions about the game, such as the opposing team, the score, and the position played. Memory can be evaluated by asking questions about events prior to the injury, such as when the last game was played, how the team got to the venue, or what the athlete did prior to the game. Immediate and delayed memory can be assessed by asking the athlete to recall a list of five words immediately and at the end of the assessment. Concentration and mental processing speed can be evaluated by asking the athlete to recite the months of the year backward or to do serial sevens. The athlete's ability to do the test may be affected by the injury, resulting in slow responses or mistakes.

Physical Findings

The level of consciousness in any athlete with a head injury can be assessed by using the Glasgow coma scale (Table 2). If the athlete is unconscious, neck immobilization should be performed by qualified medical personnel. Any athlete with a Glasgow coma score less than 13 should be rapidly transported to the nearest hospital for further evaluation.

Conscious athletes should be removed from the field of play. There may be areas of tenderness, lacerations, hematomas (large bruises under the skin), bleeding from the ears, or leakage of cerebrospinal fluid from the nose. Head injuries may result in neurological abnormalities, such as seizures, decreased vision, impaired eye movements, weakness, loss of sensation, or gait abnormalities. An athlete with any neurological abnormalities should be transported to a hospital promptly for further evaluation.

Athletes who are stable should be watched carefully on the sidelines by trained personnel to detect signs of deterioration. If there are signs of deterioration, the athlete should be assessed in hospital.

Investigations

On-Field/Office Assessment

There are various quick assessment tools that can be used on the field or in the office, including the Maddocks questions and the Standardized Assessment of Concussion (SAC). The most recent tool was developed by the Concussion in Sport Group at the Second International Conference on Concussion in Sport. The Sport Concussion Assessment Tool (SCAT) assesses orientation, immediate and delayed memory, and concentration. It can be downloaded from www.thinkfirst.ca.

Neuroimaging

Most head injuries do not require diagnostic imaging. If there are any neurological signs, such as seizures, decreased level of consciousness, or pupillary abnormalities, computed tomography (CT) or magnetic resonance imaging (MRI) should be performed to rule out any intracranial injury (Table 3).

Athletes with complex concussions and prolonged concussive symptoms should have imaging studies done (CT or MRI) as well as formal neuropsychological tests. In cases of simple concussion, imaging studies are typically normal and, therefore, are not routinely indicated. MRI is more sensitive to detect subtle structural injuries to the brain, such as contusions or diffuse axonal injury (DAI). Specialized imaging techniques are available in some centers that may be able to detect brain injuries following a concussion. These techniques include single-photon emission computed tomography (SPECT), positron emission tomography (PET), and functional magnetic resonance imaging (fMRI). These tests are not routinely available or indicated.

Table 3 Indications for Neuroimaging in the Setting of a Sports-Related Head Injury

Persistent vomiting (more than 3 times)
Prolonged loss of consciousness (more than 5 minutes)
GCS 12 or less
Focal neurological signs
Signs of skull fracture
Seizure

Source: Purcell L. Traumatic head injuries. In: Micheli LJ, Purcell LK, eds. *The Adolescent Athlete*. New York, NY: Springer; 2007:61–79, Table 3.3. Reprinted with permission from Springer Science + Business Media.

Note: GCS = Glasgow Coma Scale.

Neuropsychological Testing

Head injuries can result in cognitive-functional deficits, such as impaired attention and concentration, mild disorientation, and memory difficulties. In athletes who have sustained a head injury and who experience persistent symptoms, neuropsychological testing can help identify specific areas of impairment and can help guide return-to-play decisions. Ideally, baseline data should be obtained prior to the occurrence of a head injury so that athletes can be compared with their own baseline following an injury to determine any deficits. Baseline data are also recommended because neuropsychological tests can be adversely affected by many factors, such as test anxiety, learning disabilities, previous head injuries, psychiatric disorders, and attention deficit disorders. Even in the absence of baseline data, neuropsychological assessment can provide objective information to help guide return-to-play decisions.

A unique concern with neuropsychological testing in pediatric athletes is that children and adolescents are undergoing rapid cognitive development. Studies have shown that there is significant improvement in simple and choice reaction time, working memory, and new learning in children between the ages of 9 and 18, with the biggest changes noted between 9 and 15 years of age. These developmental improvements can potentially confound the results of postinjury tests because cognitive impairments resulting from injury may be offset by maturational improvements. Baseline testing in pediatric athletes should therefore be repeated every 4 to 6 months to account for developmental improvements in performance.

Types of Injuries

Table 4 provides data on head injuries resulting from participation in sports.

Prevention of Injury

Many sports-related head injuries can be prevented. Appropriate protective equipment, including approved helmets, is required for participation in contact sports, such as hockey and football. Approved helmets should also be worn for recreational activities with a significant risk of head injury, such as cycling, skiing, and snowboarding. It is important to wear the equipment properly and ensure that it is well maintained. Damaged equipment should be promptly replaced.

It is important for all participants in sports, including athletes, parents, trainers, and coaches, to realize that helmets will not prevent all head injuries, particularly if athletes are participating in high-risk behaviors. Athletes should respect the rules of their sport and practice fair play to minimize the risk of head injury to themselves and others. Coaches and trainers must ensure that athletes learn the proper techniques of their sport to prevent head injuries.

Enforcing the rules of the particular sport will also help prevent head injuries. Limiting checking in hockey in younger age-groups, banning checking from behind, and eliminating fighting can help prevent head injuries in hockey. Equipment changes, such as padded goalposts in soccer and football, can help decrease the incidence of head injuries. Discouraging participation in sports in which intentional head injury is encouraged can also decrease the incidence of head injuries.

Return to Sports

Any athlete who is still symptomatic from a head injury should not participate in sports. Certain head injuries can be quite serious and may preclude return to contact sports (Table 5). Intracranial hemorrhages requiring surgery are a contraindication to resuming contact sports. An athlete who has sustained an intracranial hemorrhage not requiring surgery or who has a complete recovery may contemplate a return to contact sports a year or longer after injury in selected cases. However, this decision should be made after extreme deliberation between the physician and the athlete.

For other, less serious head injuries, such as concussions, athletes should rest from sports until they are completely asymptomatic. Athletes should not return to play on the day of injury because symptoms may evolve and progress later that day or the next day. Once they are completely asymptomatic

Table 4 Head Injuries Resulting From Participation in Sports

Common	*Less Common*
Lacerations	Intracranial hemorrhage
Contusions	Epidural hematoma
Concussion	Subdural hematoma
	Subarachnoid hematoma
	Intracerebral hematoma
	Skull fractures
	Malignant brain edema syndrome
	Diffuse axonal injury
	Chronic traumatic encephalopathy

Source: Laura Purcell, M.D.

Table 5 Conditions Precluding Participation in a Contact Sport

Permanent neurological deficits
Persistent post-concussion symptoms
Spontaneous subarachnoid hemorrhage
Hydrocephalus

Source: Teasdale G, Jennett, B. Assessment of coma and impaired consciousness: a practical scale. *Lancet.* 1974;2:81–84. Reprinted with permission from Elsevier.

at rest for several days, they should progress through a medically supervised stepwise increase in activity to resume their sport. If symptoms recur during this stepwise process, the athlete should rest for 24 to 48 hours and try to progress again.

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Headache, Exercise-Induced

Exercise-induced (exertional) headaches—the kind a person gets as a result of physical exertion—affect between 1% and 40% of athletes and exercisers at least once in their lives. Runners, swimmers, divers, rowers, cyclists, aerobic exercisers, and weight lifters are in the high-risk group, and men in their 20s are the gender and age-group most often affected. The headaches can go away in as little as 5 minutes or can last as long as 2 days. At least half of them go away quickly.

Other than causing immediate discomfort, most exercise-induced headaches are usually harmless. According to the National Headache Foundation, however, up to 10% of them are caused by potentially serious underlying problems, such as tumors, sinus infections, or defective blood vessels in the brain. A study conducted in New York and published in the journal *Neurology* found that exertional headaches were a symptom of heart disease in a very small group of patients. People who exercise and get headaches as a result may need medical help to learn how to tell the difference between headaches that are benign and those that are potentially life threatening.

Causes

There are several theories but very little compelling medical evidence regarding the cause of exercise-related headaches. Exercise causes an increase in the flow of blood throughout the body, as well as a rise in blood pressure. One theory says that some of that blood reaches the arteries in the scalp and the accompanying dilation of the vessels causes pain.

A second theory suggests that these headaches may be triggered by a previous injury or condition, such as a concussion or chronic migraine headaches. Individuals may not exhibit symptoms at rest but may develop painful headaches with vigorous physical activity.

A third possibility is that air is forced out of the body through airways that are partially closed, which may happen when a weight lifter completes a heavy lift. In this situation, blood flows from the arteries to the head at a normal rate, but the strain caused by lifting increases intracranial pressure while reducing the flow of blood out of the brain through the veins.

There is anecdotal evidence to show that the exercise environment could be a contributing factor. People who live at an altitude below 1,000 feet (304.8 meters) and exercise at altitudes higher than 1 mile (1.6 kilometers) may experience headaches because not enough oxygen-rich blood reaches the brain. Exercising in hot, humid weather is more likely to cause a headache than training or competing in less extreme temperatures.

Headaches can also be sport specific. "Swimmer's headache" affects some people who jump into cold water. "Swim-goggle headaches" are caused, not surprisingly, by goggles that fit too tightly. "Footballer's headache" is a European expression used to describe headaches caused by frequently heading a soccer ball.

Symptoms

Exertional headaches occur during or immediately after strenuous exercise, but at times they can be associated with sneezing, straining, or even sexual intercourse. They have been described as throbbing headaches (as opposed to dull) that affect the whole head, and most of them subside within a few minutes or a few hours after stopping activity. Some athletes report a feeling of nausea but not vomiting. Harmless exercise-related headaches do not get worse over a period of time, they are not usually described as "explosive," and they are seldom, if ever, accompanied by other physical symptoms. When they are, it is important to see a physician.

Treatment

The simplest treatment is to stop or at least modify the activity that causes the headache or to change the setting in which a person exercises.

The anti-inflammatory drug indomethacin is very effective for both treating and preventing exertional headaches (when taken 1 to 2 hours before a physical activity). Over-the-counter pain relievers, such as acetaminophen and aspirin, may also prevent headaches, but aspirin causes gastrointestinal problems in some people.

Applying a cold pack to the head or behind the neck can help numb the pain.

Prevention

The following measures are recommended for prevention:

- Avoid strenuous activities, especially endurance events, and hot, humid, or high-altitude environments, in which exercise-induced headaches are more likely to occur
- Warm up before an exercise session by jogging or performing light calisthenics and cool down afterward by walking several hundred yards.
- Observe the 10% rule: Never increase exercise intensity, duration, or frequency by more than 10% a week.
- Use relaxation, deep breathing, biofeedback, and imagery before a stressful athletic event.
- Drink 7 to 10 ounces (oz, 1 oz = 29.57 milliliters) of water or a sports beverage every 10 to 15 minutes during strenuous exercise.
- Take breaks to avoid overheating.
- Take an aspirin, acetaminophen, indomethacin, or propranolol before exercising. (Propranolol and indomethacin must be prescribed by a physician.)

Jim Brown

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Heat Illness

Heat-related illness occurs when the body is unable to transfer enough heat through the skin to keep the body's core temperature from rising to a dangerous level. During hot weather, especially with high humidity, the normal regulation of body temperature through sweating and evaporation may not be enough. Overexertion under such conditions can place exercising athletes at risk for heat illness. Older adults, young children, and those who are sick or overweight are most at risk. Drinking fluids, replenishing salt and minerals, and limiting exposure to heat can help. This entry describes the mechanisms of thermal regulation, the forms of heat illness and their treatment, risk factors, and recommendations for prevention.

Thermal Regulation

Physical work generates heat, and the human body is capable of efficient heat dissipation and temperature regulation. As exercise begins, heat production exceeds heat loss, creating an increase in the core temperature. Receptors in the brain and muscles detect the increase in temperature and produce increased blood flow to the skin, initiating sweating. External heat from the environment can also trigger heat-dissipating mechanisms. The diversion of blood flow to the skin also affects performance, with an increase in perceived exertion and earlier fatigue.

Heat transfer from the body is accomplished through the processes of radiation, convection, conduction, and evaporation. Radiation produces loss of heat energy through emission from the skin and is most efficient at temperatures less than 68 °F. If ambient temperature exceeds skin temperature, then radiation is ineffective and may result in heat gain. Convection leads to heat dissipation through loss of heat energy to the air and depends on the wind, becoming ineffective with increasing ambient temperatures. Heat is lost via conduction when heat is transferred from a warmer to a cooler object by direct physical contact. Loss of heat through evaporation occurs when heat is dissipated through the evaporation of sweat from the skin. With increased ambient temperatures, evaporation is a very effective mode of heat dissipation, but it becomes less effective with humidity over 75%.

Heat dissipation mechanisms maintain core temperature from 95 to 104 °F. Despite effective heat dissipation, the circumstances of exercise and the environment may lead to inadequate heat loss. With increased intensity of exercise, the amount of heat produced increases and may exceed the body's ability to dissipate heat, resulting in an increased core temperature. The environmental temperature and humidity also significantly affect the processes of heat dissipation, particularly the effect of high humidity on evaporation. As exercise is continued, dehydration may develop and decrease sweat production. As these systems continue to fail, the core temperature continues to rise.

Clinical Manifestations of Heat Illness

Heat Edema

Symptoms of mild swelling of the hands and feet occur during the first few days of heat exposure. The elderly are more susceptible to heat edema, which typically is resolved with leg elevation and proper acclimation.

Heat Rash

Heat exposure leads to an inflammatory reaction with a rash consisting of small red spots resulting from blockage of the sweat pores. The associated symptoms often include itching, which can be treated with antihistamines. Less commonly, secondary bacterial infections may occur and require antibiotic treatment.

Heat Cramps

Heat cramps involve painful, involuntary spasms of the muscles after exercise in the heat. The calf muscles are most frequently involved. Electrolyte imbalance and dehydration are the suspected etiology. Treatment includes rest, massage, stretching, and hydration.

Heat Syncope

Pooling of blood in the leg muscles causes an athlete's blood pressure to drop, leading to insufficient blood flow to the brain. If the athlete develops dehydration or has inadequate cooldown after running, the problem seems to worsen. Placing the athlete in a cool environment with legs elevated, along with rehydration, will typically resolve the symptoms. An assessment for possible cardiac or neurological causes is essential.

Heat Exhaustion

The athlete may develop fatigue, weakness, headache, lightheadedness, confusion, or a lack of coordination. The core body temperature measurement rectally is below 104 °F. Symptoms are theorized to result from an inadequate cardiac response to the heat stress and the effect of increased temperature on the central nervous system. Complete assessment and close temperature monitoring are essential as progression to heat stroke is possible. Treatment includes rapid cooling and rehydration, combined with close monitoring in an appropriate medical facility.

Heat Stroke

Heat stroke is the most advanced in the spectrum of heat illnesses, and it is important to note that any of the less severe forms of heat illness may rapidly progress to heat stroke. Early recognition and prompt treatment of heat stroke are essential to lessen the risk of morbidity and mortality. The classic symptoms include a dry, hot skin without sweating; altered mental status; and rectal temperature >104 °F. Athletes, however, may still demonstrate sweating. Heat stroke may lead to serious organ system damage, such as acute kidney failure and rhabdomyolysis (destruction of muscle cells leading to multiple physiologic complications). Rapid reduction in body temperature is the first priority to enhance recovery and minimize organ damage. Immersion in ice water can rapidly decrease the core body temperature to 102 °F in about 10 to 40 minutes. Cooling with ice packs in the groin and axilla, along with cool mist fans, is also useful. The causes of altered mental status other than heat stroke must be considered during assessment. Infections, stroke, drug use, and hyponatremia (low blood sodium) are also part of the differential during evaluation. Checking the blood sodium is central to ensuring correct treatment with intravenous solutions.

Risk Factors and Prevention

Many different factors may contribute to an athlete's risk of developing heat illness. The most significant factor relates to proper hydration. Thirst occurs after about 2% loss of weight and is an inaccurate measure of hydration. Regular replacement of fluids with cool water is recommended for the exercising athlete. Since there is not much salt in the sweat of athletes, water is most appropriate to maintain fluid concentration in the body and is most easily absorbed into the system. Exercise for more than 1 hour benefits from the use of a dilute concentration of about 6% of an electrolyte and glucose polymer solution.

Acclimatization is an adaptive process whereby repeated heat exposure leads to improved cardiovascular and metabolic efficiency. Typically, acclimatization develops within 7 to 10 days of heat exposure and is sustained for about 2 weeks. The elderly and children have less ability to acclimatize.

The Wet Bulb Globe Temperature combines ambient temperature and humidity to assess the safety of exercise in a particular environment. Additionally, clothing, equipment, and time of day may affect the body's heat-dissipating ability. A prior history of heat injury and febrile illness also increases the risk of heat illness. Use of some medications, such as diuretics, antihistamines, beta blockers, and stimulants, can predispose the athlete to heat injury, so they must be used with caution.

Ellen Geminiani

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Hepatic Injury

Serious abdominal injuries occur, but these are relatively uncommon in sports. Some estimate that 7% to 10% of athletic trauma is related to the abdomen.

Anatomy

The spleen and the liver are solid organs located in the peritoneal cavity inside the abdomen. The liver is in fact the largest organ in the body, weighing 1 to 1.5 kilograms (kg) and representing 1.5% to 2.5% of lean body mass. The size and shape vary and typically match the general body shape. It is located in the right upper quadrant of the abdomen, under the right lower rib cage against the diaphragm, and projects for a variable extent into the left upper quadrant. The liver is held in place by ligaments attaching it to the diaphragm, the peritoneum, the great vessels, and the upper gastrointestinal organs. About 20% of hepatic blood flow comes from the hepatic artery and is oxygen rich; the other 80% comes from the portal vein arising from the intestines, stomach, and spleen. This blood source is rich in nutrients.

The risk of hemorrhagic shock from blunt abdominal trauma may be greater in athletes; ultrasound imaging has shown that the right and left lobes of the liver, plus the great vessels, are of greater diameter in well-trained endurance athletes than in sedentary adults.

Function

Hepatocytes (liver cells) perform numerous and vital roles in maintaining health and homeostasis. Their functions include the synthesis of proteins (albumin, coagulation factors, and hormones), the production of bile, the regulation of nutrients (glucose, glycogen, lipids, cholesterol, and amino acids), and the metabolism and conjugation of lipophilic compounds (bilirubin, cations, and drugs) for excretion in the bile or urine. The measurement of these activities to assess liver function is possible, the most commonly used being serum bilirubin, albumin, and prothrombin time (which is prolonged when coagulation factors are not being synthesized well).

Epidemiology

Although the spleen was previously asserted to be the most commonly injured intra-abdominal organ, the incidence of liver injuries may be similar. This is not surprising, considering the large size, soft substance, and unprotected position of the liver. With the evolution of computed tomography (CT) scanning, recognition of minor liver injuries has been enhanced.

There have been several case reports of hepatic traumatic injury incurred during contact sports, such as football. High-speed noncontact sports also have mechanisms that can result in hepatic injury. Motor vehicle accidents and bicycle-related events resulting in hepatic injury are reported with higher frequencies in some series. Often, other organs are also injured should the liver be involved. In the abdomen, this is most often the spleen, followed by a kidney, the pancreas, and the bowel. Head injuries, thoracic injuries, and fractures are often comorbidities, particularly in high-speed mechanisms.

Bicycle handlebar injuries have been reported to result in trauma to the liver or the biliary tract. Bicycle handlebar injuries resulting in hospitalization are reported to have an incidence of 1.15 per 100,000 in the pediatric population (18 years or less) in the United States.

Injury Mechanics

Injury can result from a direct blow, especially to the right upper quadrant; a sudden deceleration; or a fracture that displaces the right lower rib. In deceleration injuries, the liver shears a relatively thin capsule from the underlying attached parenchyma, usually at the site of the attaching ligaments. Direct blows can cause crush injury to the liver, which may result in subcapsular or intraparenchymal hematoma. Contracoup injuries are seen in children; hence, the trauma can be indirect, and contact may be to a location away from the right upper quadrant of the abdomen, where the liver lies.

Lacerations and contusions of the liver are seen and can have subacute presentations with potentially catastrophic late hemorrhage and a high mortality risk.

Severity Grading

Liver injuries are graded using the American Association for the Surgery of Trauma scale, with a spectrum from Grade I or Grade II injuries, which are considered minor (80%–90% of all injuries), to Grade III to Grade V injuries, which are severe, and Grade VI injury, which is usually fatal.

Risk Factors

Hepatomegaly results in an increased risk of injury, not only because of the increased size but also because an enlarged liver is softer than normal. Therefore, hepatomegaly is a contraindication for high-speed or contact sports.

Clinical Evaluation

The mechanism of injury, especially for lower rib fractures, is much more important than the physical exam to diagnose a possible liver injury. Individuals with liver injury who complain of right upper quadrant pain may have radiation of pain to the right shoulder or neck. These symptoms may be accompanied by nausea and vomiting. The physical exam technique should follow the traditional medical model of inspection, palpation, percussion, and auscultation. On inspection, an abrasion/contusion over the right upper abdomen may be noted; the back and flank should be regarded too in case of missed bruising. Injured athletes are typically tender in the right upper quadrant and sometimes demonstrate abdominal guarding, in which case the abdominal wall musculature is involuntarily taut. The ribs overlying the liver may also be tender. Percussion can help determine the presence of peritonitis, and auscultation can illicit bowel sounds unless an ileus has developed and the intestines have ceased to function. Hemodynamic instability may be present and can be ascertained from vital signs such as elevated heart rate and diminished blood pressure.

Laboratory evaluation may indicate aspartate aminotransferase (AST) and alanine aminotransferase (ALT) elevation, with a sensitivity of 92.9% and a specificity of 100% for a reported hepatic injury.

Management

Hospital management depends on the responsiveness of the patient and his or her hemodynamic status. The conscious athlete who is hemodynamically unstable with peritoneal signs should undergo immediate laparotomy. If the patient is unconscious or his or her physical signs are equivocal, a diagnostic peritoneal lavage (DPL) is recommended. An exploratory laparotomy is indicated if the DPL is positive. If the athlete is hemodynamically stable, a radiologic evaluation such as CT can be undertaken to determine the extent of injury to the liver and to optimize treatment.

An alternative to DPL is ultrasound, which can also be used to screen for hepatic injury. This can be performed in the emergency department and has been shown to be sensitive (85%) and specific (99%) in detecting intra-abdominal injuries.

A CT scan is warranted with any appropriate mechanism. The typical appearance of a liver laceration is illustrated in the image below. An abdominal CT scan is sensitive and specific in diagnosing liver, spleen, and retroperitoneal injuries. One study reported a sensitivity of 100% and a specificity of 96.8% prior to surgical exploration. The radiological grade on the CT scan alone may not predict a clinical outcome reliably in

Computed tomography scan of a liver laceration sustained from a bicycle handlebar

Source: Sheridan S, Coyle T, Davis C, Irwin GJ. Radiology cases from the Royal Hospital for Sick Children, Glasgow: biloma as a complication of hepatic transection due to a handlebar injury. *Eur J Pediatr Surg*. 2006;16(4):269–271. With permission.

Note: A contrast-enhanced computed tomography scan showing the hepatic laceration extending up to the porta hepatis.

Computed tomography scan of a hepatic injury sustained in American football

Source: Courtesy of David Mooney, M.D., Children's Hospital Boston.

pediatric patients. Liver injury outcomes may correlate more strongly with associated injuries at presentation and hemodynamic instability in this setting.

Unstable patients should have an immediate laparotomy. However, even high-grade injuries can be managed nonoperatively despite an imposing appearance on the CT scan if the patient is hemodynamically stable. Nonoperative management was originally successful in children, but this has now extended to adults. It involves careful hemodynamic monitoring, frequent physical exams and laboratory evaluations (e.g., serial hemoglobin/hematocrits), and strict bed rest. Hemorrhage from the liver typically occurs in the first 24 hours after injury, unlike the spleen, which can have delayed bleeding when injured. Hemorrhage from the liver is uncommon and is reported in less than 2% of the cases managed nonoperatively. Bleeding will often stop spontaneously (in 50–80% of all injuries), and even when a liver injury is determined in need of an operative approach, 70% of the time bleeding has ceased by the time of laparotomy.

With a stable clinical course, a CT scan will often be repeated after 5 to 7 days. In one investigation of hemodynamically stable children with isolated hepatic traumatic injuries managed with observation, all were discharged 48 hours after the injury if they had no abdominal tenderness, tolerated a regular diet, and had a stable hematocrit (see image, top of this page).

Return to Sports

Expert opinion previously asserted that return to play is only possible with clinical healing and an entirely normal CT scan. This often takes weeks to months to achieve after injury and has provoked some controversy recently. There are no return-to-play criteria; common sense would suggest normalization of liver function test enzymes (alanine transaminase [ALT], aspartate aminotransferase [AST]) plus a normal physical exam and a return to symptom baseline to be prerequisites for return to sports.

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See also Abdominal Injuries; Hepatitis; Hepatomegaly; Liver Conditions

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Hepatitis

Hepatitis is a general term that refers to inflammation of the liver. There are many causes of hepatitis, including infections, medications, toxins, and autoimmune diseases. Of the infectious etiologies, the most common are infections with the hepatitis A

(HAV), hepatitis B (HBV), and hepatitis C (HCV) viruses. These viruses account for more than 90% of cases of acute viral hepatitis. Acute infection with all three hepatitis viruses can result in similar clinical manifestations, including fever, abdominal pain and loss of appetite, nausea, fatigue, and jaundice. Most cases of acute viral hepatitis resolve spontaneously and carry an excellent prognosis for complete recovery. Less than 0.1% of infected individuals die as a result of acute viral hepatitis. The most common cause of death in the setting of acute viral hepatitis is the development of massive liver necrosis. A possible complication following acute infections with HBV and HCV leads to the development of chronic hepatitis.

It is estimated that there are more than 500,000 new cases of viral hepatitis each year in the United States alone, that more than 1 million Americans are chronically infected with HBV, and that greater than 3 million have chronic HCV infection. Of those individuals with chronic hepatitis, approximately 15,000 will die as a result of complications related to chronic liver disease, such as cirrhosis and hepatocellular carcinoma.

Given the high prevalence of viral hepatitis, athletic individuals are at risk for developing this disorder. Although athletes are much more likely to contract viral hepatitis as a result of activity unrelated to sports, a small risk of disease transmission during sporting activity does exist. Once an individual is diagnosed with viral hepatitis, concerns may be raised regarding the safety of ongoing sports participation. This entry will address the issue of exercise participation in the setting of acute and chronic viral hepatitis, examine the risk of disease transmission during sports participation, and discuss basic strategies to prevent the acquisition of viral hepatitis.

For many years, individuals with acute viral hepatitis were encouraged to avoid physical exertion. Then, studies conducted during the Korean and Vietnam wars, involving soldiers with acute infectious hepatitis, demonstrated that prolonged physical activity restriction was unwarranted. Soldiers who engaged in strenuous exercises once their symptoms became mild had no increased duration of the acute illness, no greater frequency of clinical relapse, and no increased prevalence of chronic liver disease, compared with soldiers who were treated with rest and avoidance of physical activity. A subsequent study involving a small group of patients with acute HBV infection demonstrated the safety of an exercise regimen involving moderate-intensity stationary biking. A joint position statement from the American Medical Society for Sports Medicine and the American Academy of Sports Medicine, published in 1995, recommended that acute HBV infection should be viewed similarly as other viral infections and that an athlete's ability to participate in sports should be based on his or her clinical signs and symptoms such as fatigue, fever, or liver enlargement. Although this publication did not discuss infection with HAV or HCV, there are no data to indicate that infection with these viruses should be managed in a different manner.

The ability of patients with chronic viral hepatitis to participate in athletic activity is quite variable. Those with mild disease activity often tolerate routine exercise quite well, and participation in higher-intensity activity and even competitive sports can be achieved without complications. Studies demonstrating the safety of high-intensity physical activity for patients with more advanced liver disease secondary to chronic hepatitis are lacking. Nevertheless, most patients should be allowed to participate in physical activity as tolerated based on their symptoms. Activity performed within the confines of their exercise tolerance is unlikely to be harmful.

An area of concern for individuals with viral hepatitis is whether the virus can be transmitted during sports participation. Direct transmission of HAV during athletic activity has not been reported. However, outbreaks of hepatitis A among groups of athletes have been seen. In such cases, the source of HAV was contaminated food or beverages consumed by members of the same athletic team. It is important to note that the risk of infection with HAV is particularly high when athletes travel to areas with less ideal hygienic conditions where HAV is endemic. Although the chances of an athlete contracting HBV or HCV are much higher as a result of non–sports-related activity, such as engaging in unprotected sexual activity or using injectable drugs, a small risk of virus transmission does exist when participating in sports where blood exposure can occur. Cases of HBV transmission have been described among sumo wrestlers and participants in American football. In contrast, HCV transmission during sporting activity has never been documented. However, non–sports-related cases of HCV infection through blood exposure raise concern about the theoretical risk of HCV transmission in sports where bleeding is more likely to occur, such as boxing. Relative to the risk of virus transmission with sexual activity and drug use, the chance of contracting HBV or HCV during sports competition is exceptionally low. As a result, it has been recommended that athletes infected with HBV or HCV should not be restricted from participating in any sporting activity.

Although the risk of transmitting viral hepatitis during a sporting activity is extremely low, some basic preventive strategies should be employed to help ensure the safety of the participants. Since contact with blood from an infected athlete poses the greatest risk of HBV and HCV transmission, prompt recognition and treatment of bleeding is critical. Individuals attending to an injured athlete should adhere to the standards of universal precautions. These are guidelines recommended by the Centers for Disease Control and Prevention (CDC) to reduce the risk of exposure to potentially infectious material and involve the use of barriers such as gloves, masks, and protective eyewear to prevent skin and mucous membrane exposure during contact with an injured athlete's blood. Preventive efforts should also focus on immunization, since safe and effective vaccinations against HAV and HBV are widely available. Unvaccinated individuals, or those who did not respond to the vaccine, who experience a known or potentially high-risk exposure to HAV or HBV should receive treatment with immunoglobulin, which is concentrated antibodies against the respective viruses. Additionally, educating health care professionals, as well as athletes, coaches, and sports officials, about viral hepatitis is another important strategy to help prevent the acquisition and spread of this disease.

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High Arches (Pes Cavus)

The foot provides multiple functions during standing and gait, including support, shock absorption, adaptation to uneven surfaces, balance, power, and direction. In any running and jumping sport, proper foot mechanics can play a key role in performance. The arch of the foot serves an important role in these functions.

The arch can fall into one of three categories: (1) neutral, (2) pes planus (flat foot), and (3) pes cavus (high arch). Most people are familiar with pes planus, or the flat foot.

The other, pes cavus, describes an abnormally high-arched foot. This type of foot is much less common. The arch is rigid, and the inflexible nature of the pes cavus foot is what creates the problem when considering the biomechanics of gait.

Historically, high-arched athletes were thought to be fast, the arch providing a type of spring. While this is not necessarily true, as described below, athletes with high arches usually need less motion control in terms of shoe type and, thus, often can run in lightweight, cushioning shoes.

Gait Cycle

A review of the gait cycle is helpful in understanding this concept of overpronation and its contribution to injury. The gait cycle consists of four phases: (1) heel strike, (2) midstance, (3) toe-off, and (4) swing. With every run, this cycle is repeated over and over, hundreds and thousands of times.

During the first two phases, the heel strikes the ground with the foot inverted (outside first) and the ankle dorsiflexed (toes pointed up), followed by the foot pronating (rolling inward) as the body weight is loaded onto the foot in midstance. During the last two phases, the foot supinates again as the weight shifts onto the toes, allowing the foot to propel and swing forward. During the cycle, the weight starts at the lateral (outside) side of the hindfoot and ends on the medial (inside) side of the forefoot as one pushes off on the toe.

Foot Anatomy

The arch of the foot is supported by the medial longitudinal, lateral longitudinal, and transverse midfoot arches. Another important structure in the arch is the navicular, which articulates with the talus proximally and the first, second, and third metatarsals distally. Situated at the "roof" of the arch, it plays an important role, accepting and transmitting much of the foot's stress.

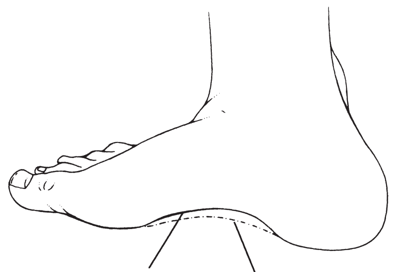
A high-arched and rigid foot will result in shock directly transmitting to these structures.

Pathophysiology

Because the pes cavus foot is rigid and unable to pronate adequately, repetitive stress is placed on the posterolateral structures of the foot. This increases the risk for injuries such as stress fractures. Injuries can also extend proximally up the kinetic chain.

Among basketball or soccer players, the rigidity and lack of pronation can increase the risk for ankle sprains.

Endurance runners or triathletes with pes cavus and high training loads often suffer from metatarsal or tibial stress fractures due to the lack of shock absorption from the pes cavus. Improper shoe choices that do not offer enough cushioning can increase the risk of stress fractures.



History

Patients with pes cavus often complain of repeated ankle sprains and difficulty in finding shoes that fit well. Many shoes do not offer adequate arch support. They may also note changes in the arch and toes, including painful calluses that can develop over time underneath the prominent metatarsal heads.

Endurance athletes may present with stress fracture symptoms as well. In this setting, a detailed history of training load, mileage, as well as other risk factors for stress fracture should be elicited (history of stress fracture, diet low in calcium, and loss of menses in women).

Physical Examination

The foot examination consists of the basic components of inspection, palpation, range of motion, and provocative tests. Inspection of the foot requires observing the foot from multiple views, including anterior, medial, lateral, and posterior. The arch is best assessed directly on the medial view. The plantar aspect of the foot should be examined for calluses under the metatarsal heads. The posterior standing view also provides information about the biomechanics of the foot. In a patient with pes cavus, the heel is noted to be in varus. Claw toes, which often result from the pes cavus foot, may be noted.

Treatment

For those with idiopathic pes cavus that is causing injuries, the standard of care involves shoe modification and arch supports.

In general, shoe prescriptions fall into one of three categories: cushioning, support, and motion control. Due to the rigid nature of the high-arched foot, a cushioning shoe is needed for pes cavus to help alleviate the lack of shock absorption. Each major shoe manufacturer has his or her own technology for shock absorption ("air," "gel," "shox," etc.). The key is choosing a well-cushioned shoe and replacing it every 300 to 500 miles (mi; 1 mi = 1.6 kilometers) before the cushioning breaks down. This will help reduce the risk of stress fractures.

A trial with over-the-counter prefabricated cushioned arch supports is recommended as well. If the support is found to wear out too quickly, a semirigid custom cushioning orthotic may be considered.

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Author's Note: The author would like to acknowledge Monica Tantraphol for her assistance in preparation of this entry.

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Hip, Pelvis, and Groin Injuries

Acute hip and groin pain occurs frequently in sports requiring twisting, pivoting, and kicking, such as soccer, rugby, and football. Symptoms can result from many structures, including the adductor muscles and tendons, the hip joint, and the hip muscles. Mechanisms of hip injury include high-velocity trauma, which may be seen in equestrian events or motor-racing accidents, and overuse injuries caused by altered biomechanics affecting the transfer of energy between the trunk and the lower limb.

Contusions (bruises) and muscle and tendon injuries are the most common injuries of the pelvis and hip. Apophyseal (the bony attachment of tendons) avulsion fractures are common skeletal injuries of the hip and pelvis in young athletes.

Groin injuries are particularly common in sports involving a lot of running, rapid changes of direction, and kicking, particularly kicking across the body. Soccer and Australian football are the two most common sports associated with groin pain. Groin injuries are also seen commonly in basketball, rugby, American football, and field hockey.

The diagnosis and management of injuries to the hip, pelvis, and groin can be challenging. Symptoms can result from numerous causes and are often diffused and insidious. Careful history taking and physical exam are essential to determine the etiology of hip and groin injuries.

Anatomy

Each half of the pelvis is made up of the following bones: the wing-shaped ilium, the pubis, and the ischium. The ilium joins the sacrum at the sacroiliac joint. The pubis and ischium join the opposite side at the symphysis pubis. The head of the femur articulates with the pelvis at the acetabulum, forming a ball-and-socket joint. There are three ossification centers of the femur: the capital femoral epiphysis, the greater trochanter, and the lesser trochanter. There are several apophyses on the hip and pelvis that have large muscle attachments, including the anterior-superior iliac spine (ASIS), the anterior-inferior iliac spine (AIIS), and the ischium. These apophyses have secondary ossification centers that allow for circumferential bone growth. The secondary ossification centers appear between 11 and 15 years of age. These apophyses are weaker than the surrounding tissues, particularly the muscles and tendons attached to them, which can result in avulsion fracture in adolescents.

Several muscle groups in the thigh, including the flexors, extensors, and adductors, attach to various points on the pelvis and hip. The sartorius, one of the quadriceps muscles, attaches at the ASIS. The rectus femoris attaches at the AIIS. These muscles function to extend the knee. The hamstring muscles, including the long head of the biceps femoris, the semimembranosus, and the semitendinosus, originate on the ischial tuberosity. The hamstrings cross both the hip and the knee and are responsible for hip extension and knee flexion. The adductor muscles, the adductor magnus, brevis, and longus, attach along the ischium. The iliopsoas attaches to the lesser trochanter, as does the vastus medialis (Figure 1).

The abdominal muscles attach to the pelvis and the pubic bone. The rectus abdominus attaches to the pubic bone. Other muscles of the abdominal wall include the external oblique, internal oblique, and transverse abdominus muscles. The inguinal ligament runs between the iliac spine or the pelvis and the pubic bone.

Evaluation of Injuries

Details of Injury

Knowledge of the mechanism of injury can help determine the type of injury. Acute traumatic events suggest muscle strains/tears. Certain activities may aggravate the injury. For instance, hip and groin pain is often aggravated by running, twisting/turning, and kicking. Aggravation of pain associated with twisting and turning activities and side-to-side movements suggests adductor-related pain. Pain aggravated by running and kicking suggests iliopsoas problems. Pain aggravated by sit-ups suggests inguinal-related pain. Performance may decrease. Pain that gets progressively worse and interferes with activity suggests possible stress fracture, nerve entrapment, or bursitis. Associated pain in the lower back or buttock indicates that the hip or groin pain may be referred from the lumbar spine or the sacroiliac joint.

The location of the pain can also help determine the structures that may be injured. For example, medial groin pain suggests adductor-related pain, whereas central groin and proximal thigh pains suggest iliopsoas-related pain.

Recent changes in training and competition, such as an increase in volume or intensity or new techniques/exercises, may contribute to an injury. Other risk factors for injury include footwear, surface conditions, and general conditioning, as well as the type of sport. The athlete's age is also important, as some injuries occur only in certain age-groups. For example, avulsion injuries of the pelvis occur only in adolescents.

"Red flag" symptoms such as fever, weight loss, night sweats, and night pain may indicate

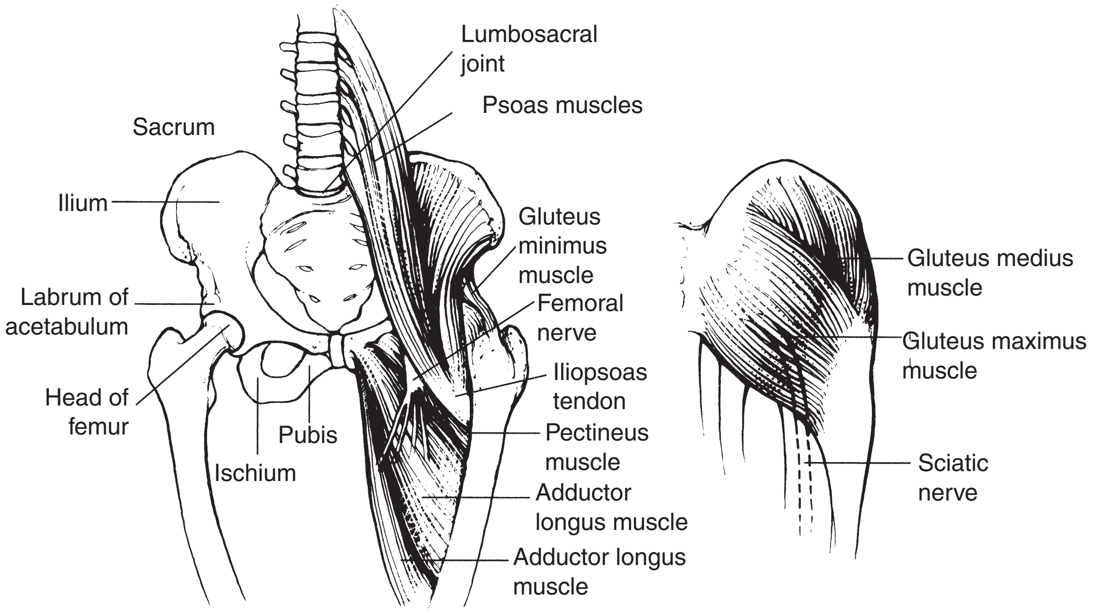

Figure 1 Anatomy of the Hip, Pelvis, and Groin

other causes of hip and groin pain, such as infection or cancer. Pain in the hip and groin region can be caused by abdominal conditions such as appendicitis, kidney conditions, conditions of the uterus or ovaries, and rheumatological problems such as ankylosing spondylitis.

Physical Findings

Hip, groin, and pelvis pain may come from the hip joint, the pelvis, the adductor muscles, the hip flexors, or the abdominal muscles. In addition, the lower back and sacroiliac joint may refer pain to the hip or groin.

An athlete with a hip or groin injury may have abnormalities in his or her gait, such as a limp. The pelvic alignment may be abnormal, or there may be abnormalities of the hips, such as excessive internal or external hip rotation. There may also be muscle wasting, bruising, or other deformities.

Range of motion of the hip may be affected by an injury. There may be decreases in hip flexion, extension, abduction, adduction, and internal or external rotation. The muscles around the hip, such as the adductor and quadriceps muscles, may be tight or may have lost flexibility. Certain tests of the hip may help determine the nature of the injury. A *hip quadrant test* is performed by the examiner, placing the patient's hip in flexion, adduction, and internal rotation. A FABER (*fl*exion, *ab*duction, *e*xternal *r*otation) test is also performed with the patient supine. The examiner places the affected hip in flexion, abduction, and external rotation, with the patient's foot next to the opposite knee. One hand applies downward pressure toward the bed on the flexed knee, while the other hand stabilizes the opposite hip. Pain in the ipsilateral lower back or buttock indicates possible sacroiliac joint pathology. A psoas muscle stretch or Thomas test may indicate hip pathology. The patient lies supine with the hips at the edge of the end of the bed. The examiner overflexes one hip, while the other hip is extended over the edge of the bed. Pain elicited in the flexed hip may indicate anterior impingement of the hip joint. Pain in the extended hip suggests psoas injury. Neural tension can be added to the Thomas test by adding cervical and upper thoracic flexion, then passive knee flexion. A positive test is elicited when the pain is reproduced and then reduced when the added tension is removed.

Strength of the hip and groin muscles may be decreased because of injuries. The athlete may be unable to flex the injured hip against resistance or adduct the hip against resistance. Injuries to the symphysis pubis may result in pain and weakness of muscles as well. While lying on his or her back, the athlete may be unable to squeeze his or her knees together against a fist with the hips and knees flexed. Abdominal muscle injuries (rectus abdominis muscle) may result in weakness, which prevents the athlete from doing a sit-up against resistance. The athlete also will be unable to hop because of muscle weakness or pain.

Injuries may result in tenderness to palpation of the soft tissues or bony tissues around the hip, pelvis, and groin, including the adductor muscles/tendons, the iliopsoas, the greater trochanter, the lesser trochanter, the iliac crest, the ASIS, the AIIS, the ischial tuberosity, the sacroiliac joints, and the buttock muscles. The pubic symphysis, rectus abdominis, and iliopsoas may also be tender to palpation. Hernias may be present on the side of the pain.

Hip stability can be assessed by the Trendelenburg test. With the patient standing, the examiner places his hands on the patient's iliac crests with the thumbs on the sacroiliac joints. The patient then stands first on one leg and then on the other. The patient should be able to keep the pelvis level. If the hip of the lifted leg falls, it indicates weakness of the gluteal muscle and poor hip stabilization.

Investigations

X-rays of the pelvis and hip should be obtained if bony pathology, such as an avulsion injury, slipped capital femoral epiphysis, or Legg-Calvé Perthes disease, is suspected. Bone scan may show increased uptake, which may confirm a stress fracture in the face of negative X-rays. Ultrasound may be used to image suspected muscle tears or confirm inguinal hernias. Magnetic resonance imaging (MRI), with/without an arthrogram, is useful in imaging the hip joint, particularly to diagnose labral tears.

Table 1 Causes of Hip, Pelvis, and Groin Pain

Common	*Uncommon*	*Must Not Be Missed*
Adductor muscle strain, tendinopathy	Iliopsoas strain	Legg-Calvé-Perthes disease
Synovitis of hip	Trochanteric bursitis	Slipped capital femoral epiphysis
Labral tear	Stress fractures (neck of femur, acetabulum, and pubic ramus)	Intra-abdominal abnormality (appendicitis, urinary tract infection, and gynecological pathology)
Chondral lesion	Referred pain (lumbar spine, sacroiliac joint)	Avascular necrosis of femoral head
Osteitis pubis (pubalgia)	Osteomyelitis	Tumors (osteoid osteoma)
Abdominal wall muscle strain (posterior inguinal wall, tear of external oblique, and rectus abdominis tendinopathy)	"Snapping" hip	
	Apophysitis/avulsion fracture (anterior superior iliac spine, anterior inferior iliac spine)	
	Rectus femoris muscle strain	
	Osteoarthritis of hip	
	Nerve entrapment (obturator, ilioinguinal, and genitofemoral)	

Source: Laura Purcell, M.D.

Types of Injury

Table 1 lists the causes of hip, pelvis, and groin pain.

Prevention of Injury

Not all injuries can be prevented. However, the incidence of injuries can be reduced. Appropriate safety equipment for a particular sport should be worn and properly maintained. Proper stretching, adequate strengthening, and proper warm-up prior to activity can prevent many acute injuries, such as muscle strains. Playing with athletes of a similar skill level can help prevent injuries as well. Overuse injuries can be reduced by employing appropriate training regimens and avoiding training errors. Training errors include increasing the rate, intensity, and duration of training too rapidly. Ensuring the general conditioning of athletes, in particular maintaining flexibility, endurance, and strength, and properly rehabilitating any injuries can help prevent further injuries. Other risk factors such as footwear, playing surfaces, nutritional factors, and associated disease states can be addressed with proper education of athletes, coaches, trainers, and parents.

Return to Sports

The most important determinant of returning an athlete to play is to ensure that the athlete can return safely and effectively. Flexibility and strength should have returned to 80% to 90% of the normal state before the athlete returns to sports to prevent further injury and allow for effective movement. Therapy is a useful adjunct to help monitor the athlete's progress and to gauge the athlete's readiness to return to sports.

For most minor injuries of the hip, pelvis, and groin, such as muscle strains, bursitis, and nerve entrapments, a period of rest to allow the pain to resolve is necessary. This rest period should be incorporated with appropriate therapy, including stretching and strengthening, to allow athletes to regain flexibility and strength. Once the pain has resolved, sports activity can be resumed. For more serious injuries, such as acute fractures and stress fractures, the period of rest may be longer. Once the pain has resolved, there is radiological evidence of fracture healing, and the contributing risk factor(s) has been modified, resumption of activity is possible.

Laura Purcell

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Hip, Pelvis, and Groin Injuries, Surgery for

Injuries of the hip, pelvis, and groin are quite common in sports. Among the most frequently occurring injuries are the following:

- Strains of the adductor and hamstring musculature
- Hip pointers
- Avulsion fractures to the iliac apophysis, the anterior-superior and anterior-inferior iliac spine, the ischial tuberosity, and the lesser trochanter
- Hip labral tears
- Osteitis pubis and sacroiliitis
- "Snapping" hip
- Femoroacetabular impingement
- Stress fractures
- Hip dislocations

In young athletes, it is important to consider other potential causes of hip pain. *Slipped capital femoral epiphysis* is a hip disorder that occurs in adolescents. *Legg-Calvé-Perthes disease* can occur in children between the ages of 4 and 8. Both normal radiographs and magnetic resonance imaging (MRI) can be useful in diagnosing these unique conditions.

Surgical Treatment

Most of the conditions described above do not require surgical intervention. Most can be treated with a period of rest, ice, and anti-inflammatory medications, followed by a focused rehabilitation program. However, it is important to recognize which conditions may go on to require surgical management. The main hip and pelvic conditions that may require surgical management are complete hamstring avulsions of the ischial tuberosity (or in the adolescent athlete, an ischial tuberostiy avulsion fracture), hip labral tears, femoroacetabular impingement, fractures of the proximal femur, and hip dislocations.

Hamstring Strains

Hamstring strains are generally treated conservatively. Grade III hamstring injuries are generally considered more severe and consist of complete tears of the hamstring insertion off the ischial tuberosity (or in skeletally immature individuals, the equivalent would be a displaced avulsion fracture of the ischial tuberosity). If conservative treatment of severe partial or complete tears of the hamstring is unsuccessful, surgical management can be considered. Surgery consists of reattachment of the avulsed tendon off the ischial tuberosity (or in the case of tuberosity avulsion fractures, an open reduction and internal fixation). Some suggest early surgical treatment of complete avulsions due to later retraction of the tendon, and thus, the timing as well as the form of treatment may be controversial in these cases. If lengthening cannot be achieved in chronic tears, an Achilles allograft may be used. Return to sports will be prolonged if surgical management is undertaken, and most likely, it will require at least 3 to 6 months of rehabilitation.

Hip Labral Tears

Initially, hip labral tears are similarly treated conservatively. Labral tears, however, may cause continued pain and catching, which may not resolve as the tear itself will persist. Advances in hip arthroscopy have made surgical treatment possible with less invasive techniques. The labrum can either be debrided or reattached with suture anchors. Rehabilitation will consist of partial weight bearing for 2 to 4 weeks, and return to sports will require at least 6 weeks if a debridement is performed and 3 to 6 months if a repair is performed.

Femoroacetabular Impingement

Femoroacetablular impingement is a condition that is gaining increasingly more attention and refers to abnormal contact between the proximal femur and the acetabulum, leading to further chondral and labral lesions of the hip. Two types of impingement are described: (1) a *cam lesion*, which is a prominence of the femoral head, and (2) a *pincer lesion*, which is the result of acetabular overcoverage. Surgical management consists of excision of the prominence leading to the impingement, either in an open fashion or arthroscopically. Arthroscopic treatment has many advantages, including being less invasive and obviating the need for dislocation or osteotomy, but it is technically much more demanding. Operative management will require prolonged protected weight bearing, and most likely, the injured athlete will not be able to return to sports for at least 3 to 6 months.

Stress Fractures of the Femoral Neck

Stress fractures of the femoral neck may be treated conservatively with non–weight bearing for approximately 6 weeks, progressing to full weight bearing if the fracture is the relatively stable compression type. There is, however, risk of displacement, particularly if the patient is weight bearing. As the blood supply to the femoral head lies along the femoral neck, displacement has implications with regard to healing of the fracture and future avascular necrosis. All distraction-type stress fractures and any patient whose compliance may be an issue should be treated operatively. Nondisplaced fractures of the femoral neck can be treated by placement of cannulated screws across the fracture site if the fracture is unstable or if there is fear of future displacement. Intertrochanteric fractures are treated with different types of fixations—usually, either an intramedullary nail-and-screw device or a plate-and-screw type of fixation—from femoral neck fractures. If treated operatively, fractures should be kept with protected weight bearing for 6 weeks, followed by progressive weight bearing and then rehabilitation. Return to sports will likely take at least 3 to 6 months.

Hip Dislocations

Hip dislocations are considered emergencies. Prompt reduction should be performed, but it should be done in a controlled, hospital setting. Following reduction, weight bearing will be restricted initially, and then progressive weight bearing will be allowed over 3 to 4 weeks. Rehabilitation is then started, but full recovery will be prolonged.

Other Injuries

Although this is much less common, surgical techniques may be used for other injuries to the hip and pelvic region. For chronic adductor strains, adductor releases have been described. For iliopsoas tendinitis, corticosteroid injections can be used. Both the lengthening and the releases have been described for iliopsoas tendinitis through both open and arthroscopic techniques. The same techniques also exist for the treatment of trochanteric bursitis and release of the overlying iliotibial band. These procedures, however, should be reserved only for cases where conservative treatment has failed.

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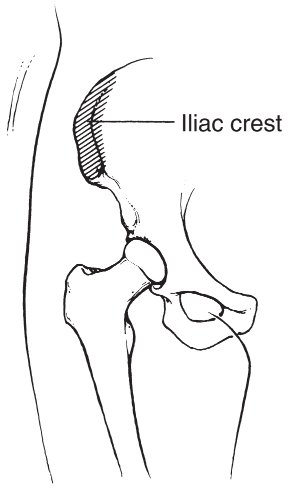

Figure 1 Hip Anatomy

Hip Contusion

A *hip contusion*, also called a "hip pointer," is in actuality either a contusion of the iliac crest and the surrounding soft tissues or a contusion of the greater trochanter of the femur. Typically, this injury occurs in contact sports such as football and rugby and is caused by a direct blow or fall. Obviously, however, this type of injury can also occur in any sport (contact or noncontact) if an athlete falls on his or her hip or side. Most of the time, these injuries are not major, and treatment is aimed at alleviating the symptoms associated with the contusion. In these cases, athletes can return to play as their symptoms resolve.

Anatomy

The anatomy of the pelvis is somewhat complicated and is beyond the scope of this book. Suffice to say, hip contusions can occur when the bony prominences in this area are injured, including the iliac crest, pubic rami, greater trochanter, and ischial tuberosity (Figure 1). The soft tissues in this area are often injured as well, and hemorrhage can occur into the muscle. This hemorrhage may occur almost instantaneously or slowly. If the bleeding into the muscle occurs at a slower rate, the athlete's symptoms and pain may actually worsen 1 day or so after the injury occurs.

History and Physical Exam

A detailed history should be obtained from any athlete complaining of hip pain. This should include the mechanism of injury and a description of the symptoms that the athlete is experiencing. Typically, the athlete can recall the exact injury, and often, the onset of pain is sudden. Activities that stress the area, including running, jumping, or simply walking, can increase the hip pain.

On physical exam, there may be an obvious area of swelling or contusion. The affected area is often very tender. The active and passive range of motion of the hip and nearby joints should be tested. Often, the range of motion of the hip will be limited by pain. The motor strength of these areas should also be tested, and motor strength should be near normal. Specifically, the hip flexors, extensors, abductors, and adductors, as well as the knee flexors and extensors, should be tested. The hip abductor and the external-rotation strength may be slightly decreased due to contusions in these areas. Sensation should be tested as well and should be symmetrical bilaterally to light touch.

Diagnostic Imaging

Plain radiographs can be ordered to rule out other injuries, including avulsion fractures of the iliac apophysis or other pelvic or femur fractures.

Bone scan can be used if a pelvis or femoral stress is suspected, if the initial plain radiographs are normal and symptoms do not improve or resolve over time.

Treatment

Early treatment during the acute phase of hip contusions consists of the RICE protocol—*r*est, *i*ce, *c*ompression, and *e*levation. The aim of these treatments is to control and decrease deep bleeding into the tissues. Anti-inflammatory medications such as ibuprofen, naproxyn, or ibuprogen can provide relief, but giving these too early may increase the amount of bleeding into the tissues. Heat, massage, and physical therapy should not be started for the first 48 hours because they may also increase the bleeding. In adults, after a fracture has been ruled out, local corticosteroids can be injected into the area, which may ultimately help alleviate pain in this area and allow athletes to return to sports quicker. As the pain decreases, passive range-of-motion and then active range-of-motion hip exercises can be started.

Severe muscular contusions can be more challenging to treat. Athletes may require long periods of physical therapy and rehabilitation that focus on maintaining flexibility, strength, and range of motion. Athletes should return to play only after they regain full strength. Early return to play before full strength has been achieved can lead to reinjury.

Complications

Deep contusions of the hip that have occurred in conjunction with significant hemorrhage can result in myositis ossificans. *Myositis ossificans* is a complication of hemorrhage and hematoma formation in the muscle, particularly if this occurs near the origin of the muscle on the bone. This often presents with abnormal bone formation around the injured site. These lesions can take up to 1 year to mature, and often treatment is symptomatic; however, in rare cases, surgical excision may be required.

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Hip Dislocation

Dislocation of the hip joint occurs when the head of the femur is displaced from the acetabular socket. This potentially debilitating injury is usually the result of a high-energy impact; although it is relatively uncommon in the arena of competitive sports, it is considered an orthopedic emergency and bears consideration in the setting of any lower extremity trauma.

Anatomy

The hip joint consists of the junction of the femur (thighbone) and the acetabulum (hip socket). The femoral head is round and fits very snugly in the acetabular cup. Because of how well they fit together and the strong muscles around the hip joint, when the femoral head is dislocated, it can be very difficult to replace in the socket. In some cases, complications may result because the blood supply to the femoral head becomes more tenuous as we age. With dislocation, the vessels do not always stretch to accommodate the new position of the femur. If the blood supply is stretched for too long, the vessels may kink and clot, which prevents adequate circulation from reaching the femoral head, potentially leading to the death of that portion of bone.

There are two main ways in which the hip can dislocate. The dislocation is described by the direction in which the femoral head exits in relation to the acetabulum: anterior (in front) or posterior (behind) (see images next page). The posterior type is by far the more common, with the majority of injuries seen in common practice the result of the knee striking the dashboard in a motor vehicle collision.

The sciatic nerve, one of the main nerves of the leg, runs posterior to the hip joint and may be compressed or damaged by the dislocated femoral head. Symptoms of damage to this nerve include

An anteroposterior radiograph of the pelvis demonstrates a posterior-superior dislocation of the right femoral head.

Source: Used with permission of the University of South Carolina, Department of Orthopaedic Surgery.

The same patient is shown after successful closed reduction of the hip.

Source: Used with permission of the University of South Carolina, Department of Orthopaedic Surgery.

pain and numbness in the foot and leg, as well as difficulty lifting the foot and ankle.

Causes

The most common cause of hip dislocation is motor vehicle collision, followed by falls. However, injury has been reported also as a result of impact in contact sports such as football, basketball, and rugby.

Clinical Evaluation

Symptoms

This injury is the result of a rapid, high-energy impact. Nearly all patients with a dislocated hip will be unable to walk and will complain of pain and decreased range of motion to the hip. Depending on the mechanism, patients may have other injuries to the affected leg, especially to the femoral shaft (midthigh) or the knee. The extremity may appear fixed in a certain position, and the patient will experience excruciating pain if attempts are made to move the leg.

Diagnosis

Patients presenting with hip dislocation will often have a difference in leg lengths or an appearance of the leg that is obviously not normal. If the injury is sustained in a sporting event or from a low-impact trauma, it may be the only injury; in motor vehicle collisions, there are often associated injuries that may even be life threatening.

In the case of *posterior dislocation*, the leg will usually be shortened, internally rotated or turned in, and flexed slightly at the hip. The patient may be more comfortable with a pillow beneath the knee to support the leg in this position.

With an *anterior dislocation*, the leg is often externally rotated, is abducted (angled away from the midline), and may be flexed or extended.

Regardless of the direction of the dislocation, a careful neurovascular exam is critical for the evaluation of the injured patient. The patient should also be subjected to careful scrutiny for other problems; the dislocated hip is often so painful that the patient may not be conscious of other injuries, even if he or she has other broken bones or internal injuries.

Treatment

Nonsurgical Treatment

Hip dislocation is considered an orthopedic emergency. Every attempt should be made to perform closed reduction as soon as it is safe for the patient. Optimally, the femoral head should be placed back in the socket, or reduced, within 6 hours of the injury; however, this should always be attempted in a hospital setting, where appropriate care can be taken to protect the patient.

For all attempts at closed manipulation, the patient must be completely relaxed. If there are associated injuries that require intubation, which requires that the patient be completely unconscious, with machines breathing for him or her, the reduction may take place at that time. If the patient is stable, the procedure may be performed under conscious sedation, in which situation the patient is relaxed but breathing without the help of machines. Regardless of the method, every consideration should be given to protect the patient's airway. If the first reduction is unsuccessful, it may be reattempted, but it is generally agreed that no more than two closed reductions should be undertaken, to protect the femoral head from any further compromise.

Surgery

There are several indications for the operative management of hip dislocations. If the joint cannot be reduced under closed conditions, an open reduction should be performed. Usually, this is due to an associated fracture where the bony fragment is blocking the femoral head from seating in the socket. The blockage may also be due to soft tissue interposition of the large muscles that surround the hip joint. Occasionally, the force of the dislocation will push the femoral head through the capsule that encases the hip joint; it is not commonly possible to obtain enough traction and excursion of the tissues to buttonhole the femoral head back through the capsule.

If the hip is reduced but not seated correctly, it is called an *incongruent reduction*. This also requires surgery as the anatomic structure that is trapped in the joint, most likely a bony fragment or muscle, must be cleared out of the joint space.

Periodically, associated fractures of the proximal part of the femur or of the acetabulum will not be evident until after reduction; in rare instances, they will actually be caused by the maneuver. In these cases, the injury should be evaluated and may require surgery to repair.

Finally, surgery must be performed on any patient who has evidence of sciatic nerve injury after the attempt at closed reduction. Given the close proximity of the nerve to the posterior part of the hip joint, it must be ensured that reduction has not caused any damage to the nerve.

Complications

The most common complication is arthritis of the hip joint; this condition occurs in up to half of all patients. A condition that is related, but slightly less common, is *avascular necrosis*. As previously described, the blood supply to the femoral head can be easily damaged. After this damage occurs, the femoral head may slowly die, which can lead to collapse and accelerated arthritis in the joint. This condition is not always painful, however, and radiographic findings do not necessarily correlate with the patient's symptoms.

Another less common complication is *heterotopic ossification*. With disruption of the structures around the hip, especially in cases of multiple trauma or fractures, excessive bone may form in the muscles and around the bones of the hip joint. This condition does not always manifest itself clinically, but when it causes problems, it may be treated with anti-inflammatory medicines or radiation therapy.

Rarely, a patient may experience recurrent dislocation. If this persists, surgery may be performed to tighten the capsule and regain stability of the hip joint.

Finally, damage to the sciatic nerve may also occur as a late complication. Under most circumstances, this is due to the formation of heterotopic ossification, which either entraps and compresses the nerve or pushes the nerve out of position, stretching the nerve fibers. If this occurs, surgery may be performed to excise the abnormal bone, which will relieve the pressure and allow the nerve to return to its normal position.

Return to Sports

After the hip joint has been reduced, a computed tomography (CT) scan should be performed to evaluate the reduction and to examine the femoral head and acetabular socket for any fractures. If no fracture is present, the patient is advised to rest for a few days, and then he or she may begin walking with crutches and limited weight bearing on the affected leg. Extreme range of motion of the hip is avoided for 6 to 8 weeks to allow the hip capsule and muscles to heal. Activity may be gradually increased during this time as the patient's pain permits. Some patients may require structured rehabilitation with a physical therapist to obtain optimal recovery.

In patients with no other injuries, it may take up to 3 months to regain pre-injury strength. Endurance training and cardiovascular conditioning may be continued throughout the recovery period as long as the weight-bearing and range-of-motion restrictions are observed. Even in patients who are asymptomatic, periodic follow-up with radiographs should be performed every 3 months for a year and at 6-month intervals for the next 2 years.

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See also Hip, Pelvis, and Groin Injuries; Hip Fracture

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Hip Flexor Strain

The hip flexors constitute the main muscle group of the anterior hip and thigh. These muscles are primarily responsible for flexing the leg forward and are used in athletic activities such as sprinting and kicking. A hip flexor pull or strain can be a debilitating injury for athletes. It can occur during a strenuous event, such as a kick or jump, or it can be the result of repetitive activity or overuse.

Anatomy

The hip flexor muscles are the iliopsoas, rectus femoris, gracilis, and sartorius. These muscles connect the pelvis to the femur and help aid in flexion of the femur forward, bringing the leg up toward the body. These muscles, along with the rest of the quadriceps muscles, which act to extend the knee, are the largest and most powerful muscles in the body. They are responsible for producing large concentric, isometric, and eccentric forces, resulting in powerful movements of the leg.

Causes

Acute injury and overuse injury are the two main causes of hip flexor strain. Acute injury typically involves a forceful eccentric contraction (contraction while the muscle lengthens) of the iliopsoas muscle. The athlete may experience one specific instance when he or she may feel the hip flexor pull. This may be associated with specific activities including sprinting, cutting, or kicking. Tight muscles and poor flexibility will contribute to a hip flexor injury. When muscles are tight, there is an increased amount of tension on the tissues. When this increased tension is compounded by an explosive movement, injury can occur (Figure 1). Soccer players are at high risk for this injury due to the powerful kicks associated with crossing passes, corner kicks, and shots on the goal. Other activities that may predispose to hip flexor strain include dancing, ballet, resistance training (weight lifting), rowing, running (particularly uphill), track-and-field events, and gymnastics.

Overuse injury may occur in activities involving repeated hip flexion or external rotation of the thigh. Injury can also be the result of overuse (repetitive kicking or long-distance running) and associated microtraumas. Microtrauma can occur in the form of a tiny, imperceptible tear. These tiny tears accumulate over time and eventually result in a strain and pain. The onset of this type of hip flexor strain is less acute and is progressive over time. Hip flexor strains of this type are often associated with a recent increase in activity.

Symptoms

The most common symptom of a hip flexor strain is pain. It occurs along the front of the hip and may radiate down the front of the thigh. Pain increases with movement, especially when attempting to lift the knee toward the chest. Running, jumping, and even walking can be painful, and sports performance may be limited. There may be a small

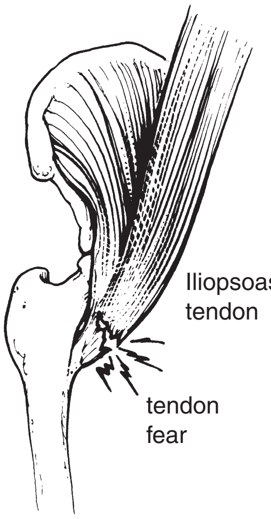

Figure 1 Hip Flexor Strain

Note: A powerful contraction of the iliopsoas muscle, usually when the leg is fully extended or trapped in place, can result in acute injury at the site where the tendon inserts into the femur.

amount of swelling, but this is not very common. Muscle spasm and bruising may also occur, depending on how severe the injury is. There is often weakness noted with activities associated with hip flexion. The injured athlete may notice a limp or pain with normal daily activities.

Diagnosis

Often, the history of a hip flexor strain is very straightforward, with either an acute injury or a history of overuse preceding the onset of symptoms. With any adult who has acute hip pain, there are "red flags" that may indicate a more serious medical condition as the source of the pain. Fever, malaise, night sweats, weight loss, night pain, a history of cancer, or a history of an immune system deficiency should prompt consideration of conditions such as tumor, infection, or inflammatory arthritis, as opposed to a simple muscular injury.

The physical exam begins with observation of the patient's gait and ability to move around the examination room. The examiner then observes the hip for asymmetry, swelling, or discoloration (bruising, redness). The exam continues with range-of-motion testing of the hip, comparing the affected hip with the normal hip to detect subtle limitations in strength or painful movements. Range-of-motion testing should include passive hip flexion and internal and external rotation. Next, the provider should test muscle strength to assess whether particular muscle groups are weak or specifically involved with the pain. Provocative maneuvers include resisted hip flexion, adduction, abduction, and external rotation and extension. In hip flexor strain, pain is increased with resisted active hip flexion and passive external rotation and extension.

Diagnostic Tests

In most cases, a thorough history and physical exam are adequate to establish a diagnosis of hip flexor strain. For high-energy ballistic injuries to the anterior hip, where the athlete describes a snap or pop at the time of injury, anteroposterior and lateral hip radiographs may be warranted to rule out avulsion or fracture. If initial conservative therapy is not effective, advanced imaging, including ultrasound and magnetic resonance imaging (MRI), can be used to assess the integrity of the muscle or the musculotendinous junction. Although ultrasound can be used for imaging following a hip flexor injury, MRI has emerged as the imaging modality of choice for diagnosing persistent hip pain in athletes because of its ability to identify the cause of injury more reliably.

The diagnosis of strains depends on the characteristic clinical findings. Hip flexor strains will usually present with tenderness to palpation over the anterior hip, with muscle weakness to hip flexion and pain with hip extension. Some athletes will also report loss of power or drive in the affected limb.

Strains are graded 1, 2, or 3 depending on severity. Grade 1 consists of minor tears within the muscle, Grade 2 is a partial tear in the muscle, and Grade 3 is a severe or complete rupture of the muscle. Symptoms and functional disability are progressive with the severity (grade) of the strain.

Treatment

Most musculotendinous injuries of the hip flexors can be treated nonoperatively. Initial treatment includes activity modification, ice, and compression to reduce pain and limit inflammation. After the pain subsides, emphasis is placed on regaining normal hip range of motion. After full, painless range of motion is achieved, strengthening exercises as well as proprioception exercises are started. The final stage of rehabilitation includes a functional return to sports activities. Surgery is rarely required for these injuries. The presence of a functional deficit despite adequate nonoperative treatment may warrant a surgical consultation.

Return to Sports

Return to full activity is permissible when the athlete has painfree range of motion and sport-specific function. This may take 4 to 8 weeks following an acute strain and up to 6 months following a chronic hip flexor strain. Typically, more severe acute injuries and chronic overuse injuries will require a longer period of recovery. It is rare for an athlete not to return to sports with proper treatment following a true hip flexor strain.

Chad Asplund and James Borchers

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Hip Flexor Tendinitis

Hip flexor tendinitis is an inflammation of the muscles and tendons that function to flex the hip, typically involving the iliopsoas musculotendinous unit. It is interrelated with iliopsoas bursitis—an inflammation of the bursa overlying the iliopsoas. Some authors have advocated the term *iliopsoas syndrome* to better describe this clinical entity as the presentation and management of both entities are the same.

Hip flexor tendinitis is an uncommon cause of hip pain, and it characteristically localizes to the anterior or medial hip. It can arise as a result of systemic arthridities such as rheumatoid arthritis, from acute injury due to trauma, or from overuse in labor or sports characterized by repetitive vigorous hip flexion and extension. Injury due to the latter is better termed *tendinosis* as it is characterized by a weakened tendon with disordered healing of multiple small injuries rather than an acute inflammatory process.

This entry addresses the relevant anatomy, etiology, diagnostic features, and management of hip flexor tendinopathy due to overuse or acute injury.

Anatomy

The iliopsoas musculotendinous unit consists of the iliacus muscle, arising from the iliac wing of the pelvis, and the psoas muscle, arising from the vertebrae of the lumbar spine. Tendons from both muscles exit anteriorly over the brim of the pelvis and join into a single tendon, inserting onto the lesser trochanter of the femur. Contraction of these muscles results in the flexion and external rotation of the hip. Extension and internal rotation of the hip places these muscles on stretch. The iliopsoas bursa, a synovial fluid–filled sac, is the largest bursa in the body and separates the iliopsoas tendon from the underlying hip joint capsule and pelvis. Occasionally, the iliopsoas bursa communicates with the capsule of the hip joint.

Etiology

Injury to the iliopsoas musculotendinous unit and the associated bursa can occur as a result of significant trauma, such as a blow to the hip or a sudden forceful extension, or from microtrauma due to repetitive hip flexion/extension activity. The resulting musculotendinous injury can vary from contusion to strain to a tendon tear or avulsion of the tendon at the lesser trochanter. The accumulation of repetitive microinjuries to the tendon results in disordered collagen healing, yielding weaker tissues prone to further injury. In contrast, injury to the bursa causes inflammation and enlargement due to increased synovial fluid production within the bursa and/or hypertrophy of the synovium. The resultant mass effect causes friction between the tendon and the bursa, resulting in secondary inflammation and injury to the musculotendinous unit.

History

Patients present with anterior hip pain associated with activity and may complain of an audible/palpable snapping of the hip. An inguinal mass may also be present.

Pain is characteristically noted in the groin or inguinal region of the hip, is aggravated by hip activity and relieved by rest, and may radiate from the hip to the knee. Patients with a traumatic history may note a snap in the hip at the time of injury, followed by pain and limping. Patients with an insidious onset of symptoms are often involved in work or sports that demand repetitive or vigorous hip activity over a wide range of motions, including running, track-and-field events, ballet, rowing, kicking sports, and strength training. Following injury, patients may experience symptoms with daily activities such as walking, climbing stairs, or standing from a seated position.

A snapping sensation in the hip can be symptomatic or asymptomatic and can be due to many possible etiologies ("snapping hip syndrome"). When present as a feature of hip flexor tendinopathy, it is termed *internal snapping hip syndrome* and is typically localized to the medial hip. Snapping arises as the iliopsoas tendon moves suddenly over the bony prominences of the pelvis.

Very rarely in the athletic population, enlargement of the iliopsoas bursa can present as a groin mass and cause secondary compression of the neurovascular structures at the hip, resulting in weakness or numbness in the distribution of the femoral nerve, leg swelling, and urinary symptoms.

Physical Examination

On inspection, the patient may present with a limp, characterized by a shortened stance phase and stride length on the involved side as the patient attempts to limit hyperextension at the hip. The hip may rest in a posture of flexion and external rotation. Tenderness to deep palpation along the course of the iliopsoas confirms the diagnosis, but it is not always present. Active flexion and adduction of the hip can elicit pain, and testing the resisted external-rotation power in the flexed hip indicates weakness. Special tests include findings of anterior hip pain with the Thomas test (i.e., passive extension of the hip) and the snapping hip sign or extension test (i.e., extension of the flexed, abducted, and externally rotated hip that elicits an audible or palpable snap).

Imaging

The diagnosis of hip flexor tendinopathy is clinical, and imaging serves mainly to confirm the diagnosis.

Plain radiographs are useful as a screening tool to rule out bony pathology as the cause of the patient's symptoms, as is a computed tomography (CT) scan, but with greater detail than standard X-rays. Bursography involves fluoroscopic X-ray imaging after contrast has been injected into the iliopsoas bursa and allows real-time visualization of the sudden medial-to-lateral motion of the iliopsoas tendon in a snapping hip.

Ultrasound can be used to statically assess the iliopsoas tendon and bursa. In tendinosis, the tendon appears swollen and has a diffusely heterogeneous hypoechoic appearance. The bursa can be visualized and measured for size by comparison with the contralateral side. Ultrasound can also be used to guide the aspiration and injection of the bursa. Reduction of symptoms by injection of a local anesthetic into the bursa confirms the diagnosis. Dynamic assessment of the iliopsoas tendon for abnormal motion in the case of a snapping hip can also be carried out by ultrasound. The tendon is imaged as the hip is moved from external rotation and flexion/abduction to extension and adduction.

MRI can demonstrate the focal or elongated fluid collection between the hip joint and the iliopsoas tendon that is characteristic of bursitis, as well as signal a change or fatty atrophy within the tendon consistent with tendinosis. MRI can also demonstrate a gap or hematoma consistent with a tendon tear.

Management

The majority of cases of hip flexor tendinopathy are successfully managed nonoperatively.

Nonoperative management consists of rest, stretching and strengthening exercises with physiotherapy, local modalities, and anti-inflammatories for 6 to 8 weeks. Rest essentially consists of avoiding aggravating activities. Stretching focuses on the hip flexors and extensors and targets the isometric power of the internal and external hip rotators. Ultrasound therapy or diathermy is applied locally to the site. Failed resolution of symptoms beyond 2 months of therapy can be addressed by ultrasound-guided injection of a corticosteroid and a local anesthetic into the tendon or bursa and continuation of the conservative rehabilitation program.

Surgical treatment of hip flexor tendinopathy is rare and reserved for patients who fail prolonged, directed conservative therapy. Surgery to address the tendon consists of open lengthening or transection of the tendon near the pelvic brim or at the lesser trochanter. Resection of symptomatic bursae or plication of a communication between the bursa and the hip joint can also be carried out.

Complications

Complications in the management of hip flexor tendinopathy are uncommon due to the conservative nature of management and are largely a consequence of invasive diagnostic or therapeutic procedures. These include local infection or septic arthritis of the hip, injury to the femoral nerve, hematoma/vascular injury, and hip flexor weakness.

Jay B. Adlington

See also Groin Strain; Hip Flexor Strain

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Hip Fracture

Hip fracture refers to a break in the bone in the region of the proximal femur or femoral neck. Fractures of the femoral neck and the proximal part of the femur occur more commonly after a fall in elderly patients with osteoporotic bone. In the athletic population, hip fractures occur far less frequently and are caused by high-energy trauma. An additional etiology of femoral neck fractures in the athlete is excessive, repetitive loads that can cause a stress fracture.

Anatomy

The hip joint is a complex structure that allows for weight bearing and a wide range of motion to position the lower limb during activity. The bony anatomy of the hip joint comprises a round femoral head seated within the bony socket of the acetabulum. A strong capsule surrounds the joint to help contain the ball within the socket throughout the range of motion and muscle force required of the hip during sporting activity.

The proximal part of the femur consists of the femoral head, the femoral neck, and the greater and lesser trochanters. The upper part of the femur develops from several growth centers that fuse and take on their adult appearance by age 14 in girls and age 16 in boys. The blood supplied to the femoral head flows closely along the femoral neck. Fractures of the femoral neck may disrupt the blood vessels and result in subsequent avascular necrosis, complicating the original injury.

Causes

The cause of hip fractures depends on the type of injury and the associated mechanism of injury. Femoral stress fractures are associated with repetitive activities such as long-distance running, jumping, and ballet dancing. They are frequently the result of training errors. Additionally, stress fractures can occur in athletes with underlying metabolic or hormonal abnormalities, making them susceptible to insufficiency-type stress fractures.

Displaced hip fractures in the athletic population are rare but can result from activities involving high speeds or energy, including motorized sporting activities, mountain biking, or skiing. These injuries can occur as the result of a fall or direct trauma to the hip. Such injuries can also be seen in collision sports such as football or ice hockey.

Symptoms

The presentation of an athlete with a hip fracture is variable depending on the fracture type and cause of injury. In patients with stress fractures or nondisplaced fractures, the only complaint may be groin or buttock pain. The pain may be activity related and may begin after a change in the training regimen or intensity. Pain may also be elicited with attempts at a straight leg raise or by taking the athlete through a range of motion at the hip.

However, in patients with an acute and displaced hip fracture, the combination of severe pain, inability to walk, and the appearance of a shortened and externally rotated lower limb is frequently seen. Recognizing the severity of the injury and the need for transport to a hospital is important when initially caring for the injured athlete to ensure prompt diagnosis and treatment.

Diagnosis

The diagnosis of hip fractures depends on the history, physical examination, and imaging studies. The nature of the injury and any associated trauma are important in making the diagnosis. Any athlete with severe pain and the appearance of a shortened and externally rotated lower leg after a collision or fall needs to be evaluated by a physician in a hospital setting with proper radiographs. The type of hip fracture can usually be determined by X-rays of the hip and pelvis.

Stress fractures of the proximal femur require an index of suspicion to be diagnosed. Critical in the history are changes in the athlete's training regimen or any metabolic or hormonal abnormalities. On physical exam, pain with active straight leg raises, pain with logrolling the affected leg, and a painful limp while walking provide clues to the possibility of a femoral neck stress fracture. Imaging studies, including X-rays of the hip and pelvis or a bone scan, may show the presence of a stress fracture. Recently, magnetic resonance imaging (MRI) has become an important imaging tool to diagnose stress fractures because of its ability to define the location of the injury, determine the extent of the bony stress reaction, and diagnose any associated soft tissue injuries.

Treatment

Nonsurgical Management

Compression-type stress fractures of the hip can be treated with good to excellent outcomes in many athletes. Often, patients are managed with a period of protected weight bearing with crutches ranging from 4 to 8 weeks. Physical therapy and pool therapy can allow the athlete to maintain some strength with some level of activity while the healing of the fracture occurs. With radiographic and clinical improvement in the stress fracture, the athlete can begin to return to activities once he or she is painfree.

Surgical Management

Surgical management of all displaced femoral neck and proximal femur fractures is recommended in the athletic population. Surgery is usually performed on an emergency basis to prevent potential complications such as avascular necrosis of the femoral head, which may result from increased pressure or interruption of the normal blood supply to the femoral head. Depending on the surgeon and the type of fracture, operative management may consist of the use of several screws, a combination of a plate and screws, or other implants to repair the fracture and allow for healing in the appropriate position.

Occasionally, stress fractures that are at risk for displacement, are tension type, or do not heal with nonoperative management require surgery, with the goal of allowing for proper healing and return to activity.

After Surgery

Rehabilitation and return to play after surgery depend once again on the severity of the injury and the surgical treatment required to fix the fracture. A period of 6 to 12 weeks of protected weight bearing with crutches to allow for fracture healing is typically required. Once the X-rays show satisfactory signs of healing, the athlete can progress to full weight bearing, with eventual return to activity below pre-injury levels and gradual progression to full activity under proper supervision.

Young-Jo Kim and Brian Brighton

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Hip Stress Fracture

Stress fractures are common injuries facing athletes at all levels and at all ages, and they can cause a significant amount of time lost from training and competition. A stress fracture can occur in one of two ways: (1) an unusual amount of stress applied to normal bone or (2) a normal or usual amount of stress applied to abnormal bone. Typically in either process, stress comes from repetitive microtrauma to the bone, as occurs, for example, when an athlete increases his or her running mileage. A stress fracture in fact is a bit of a misnomer. There is no true fracture of the bony framework. Rather, there is edema and possibly hemorrhage within the intact bone.

Our bones are made of living tissue, which can change and become stronger in response to stress, a phenomenon encompassed in the medical principle referred to as Wolff's law. This is why weight-bearing exercise is important to maintain good bone health and to prevent osteoporosis (thin or brittle bones). However, when the forces on a particular bone exceed its ability to restore itself, injury can occur. Prolonged loading (stress) without giving the bone time to heal may lead to pain and a stress fracture. If untreated, a stress fracture may progress to a complete fracture—that is, an actual break in the bone.

The site of stress fracture varies depending on the sport, and it can occur anywhere in the body. Common sites include the bones of the foot, the tibia (shinbone), the femur (thighbone), and the pelvis. Stress fractures of the foot and lower extremity are very common in running athletes, while stress fractures of the ribs are seen in rowers and golfers. Stress fractures occur in up to 15% of runners and military trainees.

This entry focuses on a specific type of stress fracture, a femoral neck stress fracture (FNSF), which occurs in the hip joint. Stress fractures around the hip can also include the pubic rami, acetabulum, and sacrum. About 5% to 10% of all stress fractures occur in the femoral neck, and it is one of the more serious stress injuries with potentially more serious consequences than other types of stress fracture. Of note, this stress fracture can occur in as little as several weeks of intensive training.

Anatomy

The hip joint is a ball-and-socket joint made of the head of the femur (ball) and a part of the pelvis called the acetabulum (socket). The head of the femur is attached to its long axis by the femoral neck. Weight-bearing forces from the body are transmitted through the femoral neck. A compressive force is transmitted along the underside of the femoral neck, and a tension force is transmitted along the top. We, therefore, refer to the sides of the femoral neck as either the compression side or the tension side. The specific location of a stress fracture in the femoral neck becomes important in terms of treatment, which will be discussed later. It is important to recognize that the blood supply to the head of the femur travels through the neck, making it subject to injury through unrecognized or nonhealing stress fractures.

Causes

Femoral neck stress fractures usually result from overloading the hip joint with excessive running or training, for example, by increasing the amount of activity too quickly. The familiar phrase "too much, too soon" certainly may apply to an athlete who develops a stress fracture. A common setting for stress fractures described in the medical literature is in military recruits, who may not be in tip-top shape when they are subjected to a high level of running and marching. Among college athletes, track-and-field athletes have the highest incidence of stress fractures compared with other sportspersons.

There are other risk factors for developing stress fractures. Certain biomechanical characteristics, such as an abnormal amount of external rotation at the hip, may place an athlete at risk. Statistics show that women are at 1.5 to 3.5 times greater risk of sustaining a stress fracture. In particular, individuals with poor dietary intake of calcium and vitamin D, both important to bone health, are more at risk. Women who have low "energy availability" are also at risk. Low energy availability can be the result of not eating enough calories, exercising too much, or a combination of both. Low energy availability can contribute to malnutrition or can cause amenorrhea (the absence of menstruation). The change in hormone levels in female athletes due to amenorrhea may contribute to the bones being at increased risk of injury, including stress fractures (see the entry Female Athlete Triad).

Symptoms

Patients with stress fractures typically present with localized focal pain that worsens as they exercise. The pain can progress to the point of occurring with day-to-day activities such as walking or simply standing. With most stress fractures, usually the athlete can pinpoint the area of pain. Unfortunately, an FNSF is a bit more difficult to localize given its location deep in the groin. The patient may complain of a deep, achy pain in the groin or hip that becomes worse with weight bearing. The patient may also complain of pain with extreme range of motion of the hip. Pain will gradually worsen with continued activity, and if not addressed, it can lead to an actual fracture of the femoral neck.

Diagnosis

Physical Exam

It cannot be overstated that a diagnosis of FNSF should be considered in any athlete complaining of groin pain and must not be missed, due to the increased risk of this stress fracture advancing to a complete or displaced fracture. Other stress fractures are usually easy to palpate due to the superficial nature of most at-risk bones. The femoral neck, however, is too deep to palpate, and pain must therefore be elicited by other means. The hop test has been shown to be helpful in diagnosis. This involves having the athlete attempt to perform a single leg hop on the affected leg. A stress fracture makes this unbearable, and the patient will likely not comply with the examiner's request. The patient will likely also have reproducible pain with passive external rotation and, more significantly, passive internal rotation of the hip.

Imaging

If an FNSF is considered, it is important to document this with imaging. Plain X-rays may show changes in the stress fracture only after 4 to 6 weeks. Often, it may be too early for an X ray to detect the bone healing, or callus, as the bone tries to respond to the abnormal stress with new bone formation. A bone scan can be helpful in diagnosing a stress fracture. This test involves injecting a radioactive material into the patient's vein. This material is picked up by areas of bone with a high rate of cell turnover, as occurs in a fracture. For a suspected FNSF, however, an MRI may be a better choice of imaging test, as it gives the physician more information about the exact location and extent of the FNSF. In particular, it is essential to learn if the FNSF is a compression- or a tension-side fracture. The tension-side stress fracture is more likely to progress to complete fracture and then to displacement. Recurrent stress on an undiagnosed and untreated FNSF can lead to progression and a disastrous complication called avascular necrosis (AVN). AVN results from a disruption of the blood supply to the femoral head and causes death of the femoral head bone. The hip joint is then irreversibly damaged, and this can lead to the need for total hip replacement in a young, healthy athlete. As mentioned previously, early detection of an FNSF is crucial.

Treatment

Nonoperative

Treatment of an FNSF depends on the location. Compression-side stress fractures are generally treated with initial rest. This usually means total non–weight bearing on crutches at first, with gradual progression to weight bearing over a course of several weeks to months. Once weight bearing is tolerated or pain-free, the athlete is slowly returned to activity and eventually to his or her sport. Cardiovascular fitness can usually be maintained during this time by another form of non–weight-bearing activity, such as swimming. Once weight-bearing activity is begun, there may be some return of pain, but this should be minimal. If at any point more significant pain recurs, the treatment plan needs to be backed up, and one should progress more slowly. The key for all stages of rehabilitation is painfree activity.

Operative

For a tension-sided FNSF or if a compression-sided FNSF continues to progress clinically despite appropriate management, some authors recommend surgical correction. The surgery involves placing a pin across the fracture line. Rehabilitation and recovery procedures are similar to those for nonsurgical treatment, with a period of non–weight bearing followed by gradual progression to full activity.

Return to Sports

If there is no underlying condition such as osteoporosis or the female athlete triad, the athlete may reasonably expect full recovery and full return to play and sports in the majority of cases. It should be emphasized that starting at the time of diagnosis, and during the management of acute injury, attempts should be made by the provider and the athlete to identify and correct any contributing factors that led to the stress fracture, whether they be internal or extrinsic factors, such as a medical condition, errors in training, or biomechanical factors.

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See also Female Athlete Triad

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History of Sports Medicine

Sports medicine is considered a relatively new medical subspecialty. For those who entered medical school 50 years ago and completed their residency training in the 1960s, sports medicine did not exist as an academic subject. At that time in North America, there were no formal medical school curricula or postgraduate fellowships available in the diagnosis and management of athletic injuries. The term *sports medicine*, which originated in Europe, was not widely used in the United States. Although there were specific physicians and surgeons providing innovative and effective medical care for injured athletes, both before and after World War II, the majority of medical institutions and teaching centers in North America had not yet established formal educational programs that included specific sports medicine subject matter, and they would not do so until the early 1970s. Our European colleagues, however, recognized the importance of sports medicine in the 1920s and convened regularly before World War II to discuss their clinical and scientific observations at international congresses. Presently, in North America, sports medicine has become a very popular subspecialty and is a respected and vital part of the educational program in all medical centers.

Sports medicine includes the study of the management of musculoskeletal injuries and the medical problems encountered by athletes during competition and training. It also encompasses the study of the physiological changes and nutritional requirements of individuals involved in strenuous athletic activity and the rehabilitative process necessary to return athletes to a safe competitive level. Sports medicine incorporates the expertise of exercise physiologists, nutritionists, physical therapists/trainers, and sport psychologists, as well as a team of physicians and surgeons. It is, indeed, a specialty that includes multiple disciplines, each of which has made significant contributions to the understanding and management of sports-related injuries.

When and where did sports medicine begin? Human beings, since the beginning of recorded time, have fulfilled their basic need for recreation, entertainment, and competition by participating in exercise, dance, and athletic activities. Paintings found in the Egyptian tomb of Beni-Hassan, dating back to 2500 BCE, depict people participating in a variety of exercises, ball games, lifting, wrestling, and physical competition. The excavations at Knossus in Crete have unveiled frescos dating back to the Minoan civilization of 2000 BCE, revealing people boxing, wrestling, and bull jumping. Although there are no medical records of the specific injuries sustained during these activities, we know that some must have occurred and can only assume that a healer or bone setter, knowledgeable in the management of sports-related injuries, must have been available to treat them.

Who was the first "team physician"? It is, of course, impossible to be sure. We do know that the first recorded athletic competition, the Funeral Games for Patroclus, organized by his friend Achilles, was described by Homer in the Iliad and consisted of the athletic events subsequently included in the ancient Olympic Games. We also know that Homer identified two physicians, Machoan, a surgeon, and Podalirius, a physician, who were the sons of Aesculapius and had accompanied the Greek troops to Troy. They were reported by Homer to have been effective in treating the injured soldiers, even performing surgical procedures. We can only assume that these two experienced doctors may have been available to treat the injuries that likely occurred from the strenuous competition during the Funeral Games. Since Homer left no injury list, we can only assume that Machoan and Podalirius may have served as the first "game doctors."

Ancient Times

Herodicus, who lived in the 5th century BCE, has been suggested to be the father of sports medicine. Although his writings no longer exist, his medical contributions and reputation have been documented by his contemporaries—Hippocrates, Plato, and Aristotle—as well as by Galen in the 2nd century CE and the authors of the earliest textbooks of medical history.

Herodicus was born in Selymbria in Thrace and received his medical education at Cnidus, which along with nearby Cos were the two most famous medical schools in ancient Greece. These towns were located in Asia Minor in an area inhabited after the Trojan War by Podalirius and his descendants. All ancient Greek physicians—the Aesculapiads—were direct descendants of Podalirius. Jouanna in his biography of Hippocrates has traced Hippocrates's lineage back 19 generations to Podalirius. However, as the years progressed, individuals without documented lineage to Aesculapius were allowed to enter medical school and practice medicine provided they agreed to abide by the Hippocratic Oath.

What best qualifies Herodicus as the father of sports medicine is that prior to entering medicine he was educated and worked as an athletic trainer. Traditionally, during the 5th century BCE in Greece, physicians were not allowed into the gymnasia where the athletes were practicing and conditioning under the supervision of trainers. Herodicus, however, had a close association with the athletes as a sports trainer, and during that time he had the opportunity to establish a treatment philosophy centered on the importance of diet and exercise as it related to health and disease.

He could also be considered the first of the "aggressive rehabilitation" proponents, recommending both stringent diets, consisting primarily of grains, and strenuous exercises, especially prolonged walking. Since this program helped control his personal medical afflictions, he ordered the same vigorous program for his patients. The excessive physical demands of his treatment protocols were a matter of concern for some and were criticized by his contemporaries, including Hippocrates, Plato, and Aristotle, as being potentially harmful to some patients. Although Plato praised Herodicus and credited him for applying "the principles of gymnastics to the treatment of disease and the preservation of health" and even stated that Herodicus "belonged, no doubt, to the rank of fully accomplished physicians," he found his treatment protocols excessive, pointing out that "by a combination of training and medicine Herodicus found a way of torturing first himself and then the rest of the world by the invention of a lingering death." Galen, during the Roman period, wrote about Herodicus's theories and treatment protocols and commented that they were harsh and potentially injurious.

Snook has made a very convincing argument that Galen should be considered the father of sports medicine. Galen's research and scientific contributions, which were based on careful animal dissections, formed the standard of medical knowledge during the Roman period and remained the foundation of medical thought into the 19th century. He was a prolific writer, producing more than 2.5 million words, including the initial description of the longitudinal contraction of muscles, the pathways of nerves from the brain to the muscles, the connections within the muscles of arteries to veins that carried the vascular flow from the left to the right side of the heart, the physiology of urine production, as well as the importance of clinical history and physical examination. In addition to his medical writing, he produced numerous treatises on mathematics, grammar, philosophy, and law.

Galen was born in 131 CE in Pergamum in Asia Minor, where he was appointed as a physician at the gladiator school by Pontifex Maximus. He was subsequently brought to Rome by Emperor Marcus Aurelius to provide care for his own family as well as the gladiators and athletes. During his career, he carried out well-documented studies in exercise physiology and reported on the effects that training, exercise, and nutrition had on individuals of all ages. He was very much in favor of athletic activities, pointing out in his "Treatise on the Small Ball" how light as well as progressively more challenging exercises can have beneficial effects on the bodies of all age-groups, including children and the elderly. However, he condemned the professionalism and excessive practices that were increasingly evident among the competitive Olympic athletes. The abuses he commonly observed among the professional and Olympic athletes of his day had begun during the ancient Greek period and also parallel the problems we currently encounter. He deplored the specialization of athletes, particularly boxers and wrestlers, which rendered their bodies overweight and out of proportion to the point where they were unfit to participate in other sports or military duty. He noted that many of these athletes subsequently developed significant disabling medical problems after their competitive years, which often led to premature death.

The professional athletes commonly moved about from city to city, changing their allegiance and often their identity to be able to compete for large monetary awards. Victories at the major competitions were usually accompanied by enticing tax benefits and lucrative pensions. These temptations frequently resulted in illegal activities and corrupt behavior among both the athletes and the trainers in attempting to obtain victories and secure the rich financial awards. These abuses along with the rise of Christianity in Rome, which opposed the traditional paganism associated with these sports festivals, were two of the reasons why the ancient Olympic Games were terminated in 393 CE. Although there is evidence that the ancient Babylonians, Assyrians, Egyptians, Chinese, and Indian civilizations participated in athletic activities and undoubtedly had medical practitioners who may have functioned as team physicians and sports medicine doctors before the time of the Roman Empire, Galen's verifiable scientific contributions and impressive body of writings justify the label Dr. George Snook gave him as the father of modern sports medicine.

During the centuries after Galen and before the modern period, there were individuals who observed and wrote about the value of exercise in the prevention and treatment of injuries. Aurelianus, in the 5th century CE, described the use of weights and pulleys as an effective form of exercise and recommended their use, along with hydrotherapy, even for postoperative rehabilitation.

During the 10th and 11th centuries, Avicenna, from Persia, and Maimonides, who lived in Egypt during most of his professional life, wrote extensively about the value of therapeutic exercise taken in moderation. They were both disciples of Galen and were in agreement with and continued to follow his medical concepts.

In the 15th century, Gerolamo Mercuriale published six books on *The Art of Gymnastics* that were very popular and remained in print for more than 150 years. In these books, he classified exercises into preventive and therapeutic categories, and using detailed illustrations, he demonstrated the proper techniques for each. These books were purchased and used by both the public and the medical professionals.

In 1602, Marsilius Cagnatus of Verona published a book titled *Preservation of Health*, in which he encouraged physicians who had knowledge of sports to become more involved in the supervision of athletic contests. He recognized how important it was for the physician to have an interest in and an appreciation of the demands of the various sports in order to provide effective care, an observation that remains true even today.

The Modern Era

The term *sports medicine* had its origin in Europe in the beginning of the 20th century. In 1910, Siegried Weissbein of Berlin published *Hygiene in Sports*, a two-volume work that described the injuries encountered in athletes and outlined treatment options. His work was followed in 1914 by a chapter on sports injuries in the *Encyclopedia of Surgery*, published in 1914 by G. Van Saar. Unfortunately, the outbreak of World War I interfered with the interest and concern physicians had with sports injuries.

In 1928, at the second Winter Olympics in St. Moritz, Switzerland, Dr. Kroll of Switzerland, Dr. Buytendijk of Holland, and Dr. Latarjet of France met with 33 other physicians and planned the First International Congress of Sports Medicine, which was held at the 1928 Summer Olympic Games in Amsterdam. The organization they formed was originally known as the Association International Medico-Sportive, but in 1933, its name was changed to Federation International Medico-Sportive et Scientifique (FIMS). This society continues to hold regular scientific meetings, has representatives and participating members from around the world, and makes significant contributions to the science and specialty of sports medicine. Since its origin, many nations have established their own national sports medicine organizations and have collaborated in regional and international educational and scientific programs.

The popularity and importance of exercise in North America was also influenced by the Europeans who immigrated to America in the early 1800s and who introduced the gymnastic exercises popularized by the Prussian Frederick Jahn (Turnen Gymnastics) and the Swedish program created by Ling. As the Industrial Revolution progressed and people moved into cities from the rural areas, exercise facilities were constructed to provide a place for workers to have physical activity. Schools also recognized the importance of regular exercise. Dr. John Warren of Boston promoted the Boston Gymnasium and assigned Dr. Charles Follen as the instructor in German and gymnastics. At the Round Hill School in Northampton, Massachusetts, in 1825, Dr. Charles Beck, who had worked with Jahn, was appointed to teach Latin and to supervise the exercise program. Mary Lyon founded the first college for women in America, Mount Holyoke, in 1837 and made daily gymnastics a requirement for her students.

Dr. Edward J Hitchcock was perhaps the most important figure in college health during the second half of the 19th century. Appointed as the instructor of physical education and health at Amherst College in 1854, during the next four decades, he required all students to have preparticipation examinations, performed regular anthropomorphic studies, maintained detailed team injury statistics, provided careful nutritional guidance, and abided by strict fitness requirements. During his career, he published more than 150 articles in the *Journal of Social Science* on numerous topics related to health and athletics. In addition, he was an able and just administrator who recognized the importance of competitive sports in student life but insisted on some administrative control of these activities. In most colleges at that time, athletics were extracurricular activities organized and run by the students and the alumni. Dr. Hitchcock established the first athletic committee, which had representatives from the faculty, the alumni, and the undergraduate students. This worked effectively at Amherst and was the blueprint copied by many colleges and universities at the turn of the 20th century.

The earliest academic publication printed in the English language was written by B. J. Byles and S. Osburn in England on the topic of sports-specific injuries and their treatment options. This was included in the *Encyclopedia of Sport* and appeared in print in 1898. The following year, Dr. E. A. Darling published an article in the *Boston Medical and Surgical Journal* in which he described the physiological changes found in members of the Harvard crew during the strenuous training for their traditional 4-mile (6.4 kilometers) race against Yale. He concluded that the effects of sustained rowing on the body were such that competent supervision was needed to ensure the safety of athletes. His statements underscored the importance of having knowledgeable sports medicine physicians available for consultation when athletes are training and competing.

Two studies published in the *Boston Medical and Surgical Journal* in 1906 and 1909 by Dr. Edward Nichols of Harvard had a significant impact on the preservation of the game of football in America. His initial paper documents the high volume and severity of football injuries, which had provoked President Theodore Roosevelt to demand that the college coaches and administrators change the rules to make the game safer. He threatened to curtail all future football contests if this was not achieved. This threat was a stimulus to form the National Collegiate Athletic Association (NCAA), which has continued to serve as the governing body for college sports. The rules were changed, and Dr. Nichols's follow-up paper in 1909 confirmed the significant reduction of serious injuries and deaths.

As indicated earlier, the study of sports medicine encompasses many disciplines, including the contributions of the exercise physiologists. In 1890, Dr. Robert McKenzie from the University of Pennsylvania published "Exercise in Education and Medicine," in which he described the effects of exercise on the body as well as the practical application of physical therapy in the treatment of injuries. Subsequently, Professor A. V. Hill from Cambridge, England, published studies for which he shared the Nobel Prize in Physiology and Medicine in 1922 with Otto Meyerhof for their elucidation of the chemical and physical processes that underlie muscle contraction. His monographs titled "Muscular Movement in Man" and "Living Machinery" discussed the factors governing speed and recovery from fatigue and also defined the concept of "the steady state of exercise" and "oxygen debt." His presidential address at the British Association for the Advancement of Science in 1925 was titled "The Physiological Basis of Athletic Records" and remains a classic today. Two other major contributors to this specialty were A. V. Bock and D. B. Dill, who edited and published the third edition of F. A. Bainbridge's *The Physiology of Muscular Exercise*, adding new material from European scientists and data from the Harvard Fatigue Laboratory, where they performed their studies. Another international organization that provided educational and scientific research information around the world was the International Council of Sport and Physical Education, established as a subdivision of UNESCO (United Nations Educational, Scientific and Cultural Organization) in 1960. This council's research committee was chaired by Professor Ernst Jokl, a highly respected exercise physiologist from the University of Kentucky. Many nations and scientists were able to participate in these informative meetings and benefit from the exchange of research and educational material.

During the early decades of the 20th century, it was not uncommon for physicians to function as both coaches and team physicians. Perhaps, the most famous was Dr. Walter Meanwell, who was the professor of physical education at the University of Wisconsin and head basketball coach. Although known primarily as a winning coach, he published an article in 1924, "The Science of Basketball," that included a section dealing with the recognition and treatment of injuries. Dr. Marvin Stevens was a surgeon who served as the Yale football coach from 1924 to 1932, and he also wrote about the mechanism of athletic injuries that he observed in the fields or from his review of game films.

Organizations

As noted previously, the Europeans had established an international sports medicine organization, FIMS, well before the need for one was recognized in North America. Following World War II, sports medicine physicians in the United States recognized the value of a collaborative effort and founded the American College of Sports Medicine in 1954. The multidisciplinary membership consists of clinical physicians and surgeons, as well as physical educators, physiologists, and other scientists, who continue to meet regularly and publish their findings in their journal *Medicine and Science in Sport*. This remains a highly respected and productive organization that addresses the full spectrum of sports medicine issues.

The American Medical Association established an ad hoc committee on The Medical Aspect of Sports in 1954. Its chairman was Dr. Augustus Thorndike of Harvard College, whose 1938 book on athletic injuries was innovative and popular, extending through five editions. The other members of this committee included Dr. Carl Badgley of Michigan; Dr. Graeme Hammond, an Olympic physician from Boston; Dr. "Brick" Mueller, a Rose Bowl hero from San Francisco; and Dr. Allan Ryan, a former Yale track athlete, professor at the University of Wisconsin, and respected author of many articles and books on sports medicine. Dr. Thomas B. Quigley, also of Harvard, was subsequently added to the committee, and recognizing the needs of athletes, the committee published the Athlete's Bill of Rights, which stated that athletes were entitled to good coaching, good officiating, good equipment, safe playing facilities, and appropriate medical care independent of the influence of coaches or administrators.

The National Athletic Trainers Association (NATA) and the Sports Physical Therapy Section (SPTS) of the American Physical Therapy Association (APTA) are organizations that have provided vital care to injured athletes and whose members work collaboratively with team physicians in caring for their mutual patients. Although the profession of athletic training extends back into antiquity, in North America, Samuel E. Bilik is considered the father of athletic training. While attending the University of Illinois, he worked afternoons as a trainer and in 1914 published the first texts on this subject, *Athletic Training* and *The Trainers Bible*. Beginning in the 1920s, the Cramer brothers (Cramer Products) supplied training rooms with the essential products of their profession and helped stimulate interest in the profession by sponsoring workshops around the country. The original NATA was founded in 1938, but World War II interrupted its development. In 1950, NATA was reorganized by 125 attendees at a meeting in Kansas City sponsored by Cramer Chemical Company. The first formal meeting of NATA was held in 1951, and the society has continued to grow and contribute to sports medicine knowledge. In 1956, their research and clinical papers were published in the NATA journal. This respected publication is now known as *The Journal of Athletic Training*. In 1948, Indiana University introduced the first 4-year college program to grant a degree in athletic training. By 2008, there were 352 accredited college programs in North America, and the membership in NATA had grown to more than 30,0000, attesting to the interest in and significance of this profession as a career. In 1971, a certification examination was introduced to ensure the competence of the graduates of the athletic training programs.

The SPTS of the APTA was established in 1973 by 75 physical therapists dedicated to a career in sports therapy. They had their first formal meeting in 1974 and elected Ron Peyton as president. This subspecialty within physical therapy has continued to grow. It is now one of the largest sections in APTA, with 6,000 members. The American Board of Physical Therapy Specialties was established, and a board certification has been required since 1986. There are now 640 sports therapy clinical specialists who have been certified. Recertification every 10 years is also a requirement to ensure continued competence. It also has a successful journal, *The Journal of Orthopedics and Sports Physical Therapy*, which was begun in 1979 and is currently the largest physical therapy publication. The SPTS has worked collaboratively with the American

Orthopaedic Society for Sports Medicine (AOSSM), NATA, and the American Medical Society for Sports Medicine (AMSSM) in educational projects and has established postgraduate fellowships in its specialty, the first being at the Gunderson Clinic in 1992. Its vision is that all sports physical therapists will have doctoral-level training by 2020.

The AOSSM had its organizing meeting in 1972. It evolved from the American Academy of Orthopaedic Surgeon's Committee on Sports Medicine, which was founded in 1964, chaired by Dr. Jack Hughston, and arranged three educational meetings annually on the upper extremity, the lower extremity, and general sports medicine problems. The founding members of the AOSSM recognized the need for an orthopedic subspecialty society dedicated to sports medicine that would provide a more effective vehicle for collaborative studies, research, and educational programs. Dr. Don O'Donoghue of Oklahoma, Joe Godfrey of Buffalo, and Jack Hughston of Columbus, Georgia, all nationally recognized team physicians, served as the first three presidents of the organization. During the years since the AOSSM was founded in 1972, the parent Academy of Orthopaedic Surgeons has passed the responsibility and leadership in providing sports medicine educational programs for its members to the AOSSM. In 2008, there were more than 2,000 active members in the society. The research and educational materials submitted and presented at its meetings have been published in the *American Journal of Sports Medicine* since 1972. Members of the AOSSM have established certified orthopedic sports medicine fellowships within their academic and clinical practices, and following completion of one of these accredited fellowships, the fellows can take the formal certification examination to become credentialed as sports medicine specialists.

Several internists and primary care sports medicine physicians who had been members of the American College of Sports Medicine or had done sports medicine fellowships with their orthopedic colleagues saw the value of forming their own primary care subspecialty organization. Dr. David Hough, Dr. John Lombardo, Dr. Doug McKeag, Dr. Lee Rice, and Dr. Jim Puffer, along with 15 other pediatric, emergency medicine, family medicine, and internal medicine practitioners, organized the AMSSM and held their first meeting in 1992. The AMSSM's membership had grown to 1,124 by 2007, and the members have continued to produce excellent research and clinical studies, which are printed in its publication, the *Clinical Journal of Sports Medicine*. The AMSSM also collaborates to produce the annual Team Physicians Courses, which are cosponsored with the AOSSM and the American College of Sports Medicine (ACSM). Members of the AMSSM are able to take a certification examination that qualifies them as credentialed sports medicine specialists.

The international interest in sports medicine has continued and is confirmed by a number of impressive organizations that were formed during the decades of the 1970s and the 1980s. The organizational meeting for the International Society of the Knee (IKS) was held in Rome in 1977, and their first congress was convened in 1979 in Lyon, France, with Dr. Albert Trillat serving as the president. Dr. Ian Smillie of Scotland and Dr. Jack Hughston of the United States were the next two presidents and hosted the meetings in 1981 and 1983, respectively. Since the International Arthroscopy Association (IAA), which had been founded in 1974, shared many common interests and members with the International Society of the Knee, these two organizations began to meet at the same locations in 1985 in Sydney, Australia, joining together for 1 day of shared scientific presentations during their separate meetings. In 1995 in Hong Kong, the IKS and IAA voted to merge and become ISAKOS, the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine. The first meeting of ISAKOS was held in Buenos Aires, Argentina, in 1997, and Peter Fowler of London, Ontario, served as the first president. This organization has grown significantly with the addition of international members from numerous counties and all continents. Along with FIMS, ISAKOS has become an important and respected international sports medicine society.

Regional and national societies continued to form through the decades after World War II. Sports doctors from Switzerland, Austria, and Germany formed GOTS, the German Orthopaedic Traumatology and Sports Medicine Society; and in

1984, the first congress of ESSKA, the European Society of Sports Traumatology, Knee Surgery and Arthroscopy, was held in Berlin, Germany, with Werner Muller of Switzerland serving as the first president. These educational and research societies, as well as other regional and national societies around the globe, remain active participants in the scientific and clinical study of sports injuries.

As international interest expanded, Asian, Western Pacific, and South American countries formed their own national and regional sports medicine societies and have continued to collaborate in the international meetings with ISAKOS, AOSSM, and FIMS. In the 1980s, an exchange program was conceived by Dr. John Feagin of the United States and Dr. Werner Muller of Switzerland, in which three young sports medicine fellows and one senior representative of AOSSM would visit the European sports medicine centers and a similar number of European colleagues would go to North America to participate in an educational experience. This was a very popular and valuable experience for all involved and has been expanded to include similar exchange programs with Asian, Pacific Rim, and South American colleagues.

Conclusion

A historical review of sports medicine is by necessity selective and, therefore, may be criticized as being incomplete. Many books have been written about the history of medicine from ancient civilizations to the present time, incorporating the achievements of physicians from many continents and numerous societies. I sincerely apologize to those individuals and organizations whose contributions I have failed to include in this entry.

Sports medicine is an ancient subspecialty that has attracted the interest, scientific talent, and enthusiasm of many modern medical practitioners and scientists. In addition to the national and international organizations mentioned above, individuals and organizations have produced important basic science and clinical studies on sport-specific as well as anatomic region–specific injuries. Time and space do not allow one to mention all the important contributions these individuals have made or to list all the impressive surgical advances made in the reconstruction of upper and lower extremity injuries that have allowed athletes to return to competition more quickly and safely. It is clear that the problems created by sports injuries are of global interest, and therefore, it is important that the clinical and scientific cooperation continue both internationally and regionally so that there will be further advances in our understanding and management of athletic injuries.

Arthur L. Boland

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HIV AND THE ATHLETE

The human immunodeficiency virus (HIV) pandemic continues to extend worldwide and as such may have an impact on individuals in all walks of life, including athletes. This entry discusses the nature of HIV disease and its recent epidemiology. There follows a description of how HIV disease might present and become diagnosed in an infected athlete. A review of the treatments that are available and at what stage in the disease process they might be initiated is presented next. Consideration is given to how athletic performance might be adversely affected by the disease, including by the infection itself, by the psychological impact of the diagnosis, and by the side effects of the medication. How training and exercise might affect progression is debated, followed by an analysis of safety of participation in sports—although it is clear that transmission risk is very low compared with most other infectious diseases in sport. Finally, varying legislation worldwide is discussed, which chiefly concerns not just the requirement to test but also travel restrictions that may detrimentally affect participation of athletes in their competitive sporting activities.

Epidemiology

The 2008 global summary of the acquired immune deficiency syndrome (AIDS) epidemic from UNAIDS (The United Nations Joint Programme on HIV/AIDS) estimates that there are more than 33 million people living with HIV, 2.7 million new HIV infections per year, and around 2 million deaths due to AIDS and complications of the infection. While most of the burden of the infection remains in sub-Saharan Africa and South and Southeast Asia, the pandemic continues to spread and increase in most countries worldwide.

HIV is transmitted through bodily fluids, in particular blood, seminal fluid, vaginal secretions, and breast milk. The main route of transmission is unprotected sex with an infected partner, which is thought to account for 70% to 80% of infections globally. This may be heterosexual or homosexual sex. The risk of transmission is increased by the presence of other sexually transmitted infections and decreased by circumcision. Sexual transmission is likely to be the commonest way in which an athlete might become infected. Blood and blood products, for example, infected blood transfusions, and organ or tissue transplants may also lead to infection, although this will be markedly reduced with appropriate levels of screening. Injecting illicit drugs still continues to lead to new infections with HIV as well as the other bloodborne viruses, hepatitis B and hepatitis C. Reuse of needles and inadequate sterilization for medical care may also be an important cause for the epidemic in some parts of the world. There is thus a risk from contaminated injection equipment, which could possibly lead to infection in athletes who use injectable products to legally (or illegally) boost their performance. Other modes of transmission are from an infected mother to the child at birth or through breast-feeding, which leads to some 5% to 10% of all HIV infections worldwide. Considerable efforts are being made to reduce this risk by the use of antiretroviral therapy for the mother and/or the child.

It is important to stress that HIV is not transmitted by casual physical contact; mosquito or other insect bites; kissing; coughing or sneezing; sharing toilets, changing facilities, showers, or other washing facilities; or consuming food or drink handled by someone who has HIV infection.

Clinical Effects of HIV Infection

Probably, most people who get infected with HIV develop acute symptoms (primary HIV infection, sometimes called an HIV seroconversion illness) within a few days to a few weeks of exposure. However, these symptoms may be dismissed as an ordinary flulike illness as the commonest symptoms and signs are nonspecific, such as fever, sore throat, and malaise. There may also be a rash or swollen lymph glands. However, the clinical presentation may show great variation as a whole host of other symptoms are possible, extending from diarrhea and weight loss to meningitis, or there may be very mild symptoms that may mean that the diagnosis is not entertained. Even if a patient presents to the doctor, the diagnosis may be missed, particularly if there appears to be no history of a risky activity. Usually, the symptoms resolve within 2 to 4 weeks, during which time the immune system controls the virus from its initial high levels of replication, and infected individuals may feel well for several years only to become symptomatic again when the immune system has been sufficiently damaged. At this stage, there is the risk of the HIV-related opportunistic infections and tumors (AIDS). Some people's immune systems control the virus so well that they remain healthy for many years (so-called long-term nonprogressors), whereas others succumb more rapidly.

One key factor, which can be measured, is the number of CD4+ lymphocyte cells (a subset of white blood cells important in controlling infection), and the numbers of these cells in the blood is used in guidelines to recommend when anti-HIV (antiretroviral) treatment should be started. Another commonly used test is to quantify the amount of HIV in the blood (HIV viral load), which tends to be higher in those who progress more rapidly. The levels of HIV in the blood around the time of seroconversion are particularly high, which increases the risk of transmission by any of the exposure categories discussed above.

The Importance of Early Diagnosis

Over recent years, there has been a lot of debate about how HIV infection might be detected earlier given the findings from ongoing surveillance studies that a significant proportion of HIV infection in the community remains undiagnosed. This might lead to people presenting in a late stage of the disease already with serious illness or with unwitting spread of infection. Thus, wider use of HIV testing is being recommended, particularly in patients with clinical conditions that might indicate the presence of HIV infection. There are now a number of guidelines being developed around the world recommending HIV testing in these HIV indicator conditions, such as tuberculosis or some severe skin complaints, and also in certain clinical settings such as antenatal clinics or where it is known that HIV prevalence in a population is greater than 1:2,000.

Antiretroviral treatment guidelines continue to evolve with recommendations to start treatment at earlier stages (with higher CD4 counts) than previously as the drugs become better tolerated and with the realization that HIV causes a wider range of problems than thought hitherto. There is thus an increased risk of heart and kidney disease as well as the traditional AIDS diagnoses, such as *pneumocystis jirovecii* pneumonia (PCP) and various tumors. How might the decision to commence on antiretroviral treatment affect an athlete? Even if he or she was otherwise well, the athlete would be advised to refrain from competition and major training for the first 3 months while he or she adjusts to the medication and it could be seen if he or she were tolerating the therapy well and not experiencing any significant side effects. After this initial period, the athlete is likely to benefit from the renewed vigor associated with improving immunity and relatively little inconvenience as the new regimens often have a small pill burden and are easy to take. It is possible of course that the medication may have demonstrable effects on the blood tests used for monitoring athletes, and at least one commonly used antiretroviral, efavirenz (Sustiva, Stockrin), has on occasion caused a false-positive test when screening for cannabis. This is mentioned in the pharmaceutical data sheet for Sustiva. Another important possible effect of the anti-HIV (antiretroviral) medication is that it may lead to important drug interactions with other prescribed or over-the-counter medication, and it is important that the athlete not take anything else without discussing it with his or her pharmacist or doctor.

Effects of Exercise on HIV

Generally speaking, exercise is beneficial for one's health, and this assertion also holds true for those who are infected with HIV. A number of studies have shown improved levels of immunity (including CD4+ lymphocyte counts) associated with exercise and no adverse effect on HIV viral load, and there is no suggestion that extreme exercise makes HIV infection progress more rapidly. Furthermore, progressive resistance training (circuit weight training) can also help develop muscle mass and muscle strength and plays a key role in maintaining bone mass, which has a tendency to decrease in HIV infection. Lifestyle modification with a better diet and more exercise in HIV-infected nonathletes has been shown to improve abnormal fat distribution (lipodystrophy), a condition that was particularly associated with some of the earlier antiretrovirals used to treat HIV. Psychological benefits and general improvements in health have been seen with exercise in many other chronic illnesses, and HIV infection appears to be no exception.

Prevention of HIV Transmission in Sports and Recreation

The risk of transmission of HIV during sporting activity is very low and is less than with the other blood-borne viruses, hepatitis B and hepatitis C. There has been one reported case of seroconversion of HIV as a result of a bleeding injury in a football match in Italy. However, a subsequent review of this early report in 1990 suggested that there was not enough evidence to confirm that transmission had occurred during this sporting activity and that the event could have occurred in the drug dependency rehabilitation center where the man worked. Transmission has also been reported in bloody street fighting; however, the risks here are likely to be greater than those of the physical contact in contact sports. Various risk estimates have been made suggesting that transmissions, even in contact sports, are likely to be lottery figure numbers of less than 1 in 1 million risks. The risk of infection by HIV and other blood-borne viruses during participation can be further reduced to negligible levels if universal precautions are introduced and observed. The following suggestions are made in many national and regional sporting guidelines:

- All blood and other body fluids should be considered infective regardless of circumstance.
- All sports persons should be encouraged to promptly report injuries, particularly those leading to bleeding, as it is in the best interest of all concerned.
- All injuries, especially bleeding wounds, should receive proper, adequate first aid using proper equipment, such as gloves.
- Blood should be cleaned from wounds with soap and water or antiseptic.
- Athletes with bleeding injuries (not minor cuts or abrasions) should be removed from an event as soon as possible.
- A blood-soaked kit should be promptly changed.
- Any skin injuries—for example, abrasions, cuts, or oozing wounds—should be covered during sports activities.
- Water containers should be available individually for each player in contact sports. Athletes should use squeeze water bottles.
- Appropriate protective equipment should be used at all times, including mouth protectors, in contact sports.
- Any equipment contaminated with blood should be removed from the sports activity area—for example, a wrestling mat.

Legislation Including Travel Restrictions

A number of professional boxing authorities require regular HIV testing and do not allow those found to be positive to participate. It is clear, however, that very few infected boxers have been identified by the organizations that have adopted this policy.

A more extensive restriction is the fact that many countries have regulations denying entry, stay, or residence based on HIV status. A recent review (2008) documented a total of some 67 such countries, which is clearly discriminatory. It is also pointless from a public health point of view as all these countries have their own endemic HIV populations. UNAIDS and other bodies have debated the injustice of these regulations and have made statements and recommendations to curtail the restrictions. Up-to-date information can be found in the website given in the Further Readings.

Conclusion

There have been major improvements in the management of HIV infection in recent years. If diagnosed in an athlete at an early stage, appropriate support and clinical monitoring can take place, which will allow maintenance of good health for many years and allow the athlete to continue participation in his or her sporting activity. There is no suggestion that the latter will be detrimental to the athlete's health, and it may indeed be beneficial. Should antiretroviral treatments be required, these can be instituted in a timely fashion before significant symptoms appear. Furthermore, newer treatment regimens appear to be better tolerated and are less likely to cause long-term side effects that might affect the athlete's sporting prowess. Athletes should be reminded that they are much more likely to catch HIV infection from unprotected sex (or the use of contaminated injection equipment) than from their sporting activities, where transmission risk is negligible, and most concerns are unfounded and are due to prejudice and stigma.

David A. Hawkins

See also Benefits of Exercise and Sports; Blood Transfusion; Blood-Borne Infections; Boxing, Injuries in; Circuit Training; Dermatology in Sports; Exercise and Disease Prevention; Immune System, Exercise and; Infectious Diseases in Sports Medicine

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Websites

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Centers for Disease Control and Prevention, HIV/AIDS: http://www.cdc.gov/hiv

Global Database on HIV-Related Travel Restrictions: http://www.hivtravel.org

HIVSports.org: http://www.hivsport.org.uk

Joint United Nations Programme on HIV/AIDS: http://www.unaids.org

Home Exercise Equipment

Home exercise equipment qualifies as any resistance-based or cardiovascular-oriented item that will assist a person toward attaining a desired state of physical fitness. For people who wish to exercise but prefer not to join a fitness center, home exercise equipment offers the opportunity for an equally effective workout at home. The sports medicine professional will be able to provide sound advice on the equipment best suited to individuals according to their fitness goals and with the aim of prevention of injury.

Home Exercise Equipment Needs Analysis

Before prescribing home exercise equipment for individuals, the following information must be gathered:

- Fitness goals
- Available space
- Budget
- Time constraints
- Intrinsic motivation

Fitness Goals

Fitness goals are very important when deciding whether or not to advise an individual to invest in equipment such as treadmills or resistance training equipment. Investment in equipment for an endurance sport participant will be significantly different from that for a person who has recently suffered a heart attack, since their fitness goals obviously will be different.

Space Considerations

Space is a factor when purchasing fitness equipment for the home. Cardiovascular training equipment can take up a lot of space without offering versatility of use. This can also be the case with multigym equipment. Both are better suited for large dwellings than for a relatively small condo or apartment.

Budget and Time Constraints

Budget and time constraints usually will determine the type of equipment that is purchased. If the budget is limited, then the home exercise equipment will generally be basic and rather limited in versatility. However, if finding the time for exercise is an issue, then purchase of equipment with only basic functions and limited versatility is advisable.

Difficulty in finding the time to exercise is one of the major reasons why people do not exercise at all. Therefore, the home exercise equipment must be easy to use, with little or no setup involved. Resistance training equipment must allow a person to "grab and go." Cardiovascular equipment must allow a person the option of a "quick start."

Intrinsic Motivation

Intrinsic motivation is perhaps the most important factor. Some will invest heavily in home equipment assuming that the cost will create the motivation to use it. However, this is not usually the case. It's common for people to get sidetracked with domestic chores and pursuits, so that fitness becomes a low priority. If a person's intrinsic motivation is low, then having a personal trainer come to the person's place of residence initially or intermittently may increase motivation and accountability.

Cardiovascular Exercise Equipment

Currently, the most popular home equipment is cardiovascular equipment, including the following:

- Treadmills
- Elliptical trainers
- Upright/recumbent bikes
- Rowing machines
- Stair steppers

Treadmills

Treadmills were once the most popular piece of cardiovascular equipment until the recent development of elliptical trainers. Home-use treadmills are produced by dozens of fitness companies for walking and jogging on a level, declined, or inclined surface. The tread surface is a heavy-duty belt, varying in length and width, that is propelled by a motor no larger than a lawn mower engine. The size of the belt can be very important for someone who has a wide gait and long stride. If the belt is narrow or short, the risk of a person falling off is significantly higher. Most treadmills require a power source varying between 110 and 220 volts. There are, however, a few smaller, self-propelling treadmills on the market that are less durable and designed for walking.

Elliptical Trainers

Elliptical trainers have seen the highest increase in sales over the past decade due to the low-impact nature and a movement pattern similar to jogging. Many runners will look to this piece of equipment for cross-training so that the amount of impact on the ankles, knees, and hips is minimized, and they can elicit a training effect similar to jogging or running. Elliptical trainers have varying stride lengths, but most commonly they are between 18 and 24 inches (in.; 1 in. = 2.54 centimeters) in length. Other variables on this apparatus include upper body components where the person can mimic cross-country skiing.

Stationary Bikes

Stationary bikes primarily come in two models: upright and recumbent. Upright stationary bikes emulate the design of traditional hybrid bicycles, which have the rider in a slightly forward flexed posture with the handles in front and approximately shoulder width apart. Upright stationary bikes have saddles/seats much larger than a traditional bike's, with the rider's comfort in mind. Most electronic upright stationary bikes have a multitude of programs that the rider can use to focus on different components of his or her cardiovascular endurance.

For the cycling enthusiast, there are basic, non-electronic stationary upright bikes used for group fitness classes that closely replicate the resistance and ergonomics of performance road bicycles. The footprint of this type of stationary bike is significantly less than that of the electronic upright stationary bike.

Recumbent electronic stationary bikes provide the rider with a back support, while his or her feet are positioned out in front. This position is significantly different from that of the upright bike and, in general, is much more comfortable for the rider. People with back disorders or other orthopedic complications will benefit from riding on a recumbent bicycle more than an upright, stationary bike due to the ergonomics providing the rider with greater support on the lumbar and thoracic spine. Recumbent electronic stationary bikes are self-powered like the electronic upright stationary bike. The recumbent electronic stationary bike has similar programs to provide the rider with variations in his or her endurance training.

Rowing Machines

Indoor rowing machines, also called ergometers or "ergs," are another very popular piece of exercise equipment that can be found in all fitness centers and in many home gyms. Ergs have a much different physiological demand from that of treadmills, ellipticals, and stationary bikes due to the significant demand on the upper body in the movement pattern. Rowing machines are long and slender with a seat that slides forward and backward on a steel rail. As in a bicycle, the handle is attached to a chain that connects to a flywheel that provides the rower with drag and resistance. The indoor rowing machine is excellent for people with orthopedic issues, due to its low-impact nature. People with chronic back troubles should consult with their doctor or orthopedist prior to investing in this piece of equipment for home use. Indoor rowing machines are self-powered with a small LED (light-emitting diode) that is battery operated to provide the rower with feedback on the pace and distance that he or she has rowed and the duration he or she has been exercising.

Stair Stepping Machines

The stair stepping machine is another very popular cardiovascular machine that replicates the motion of walking up stairs. There are two types of stair stepping pieces of equipment: stair climbers and step mills. The first of these pieces of equipment is self-powered and takes up the least amount of space of all the cardiovascular machines discussed thus far. Two pedals approximately hip width apart are controlled by an alternator that allows the pedals to have variable stepping heights.

Step mills are another type of stair stepping machines. Step mills are significantly larger than the stair climbers, with a much higher price point. The difference between a step mill and a stair climber is that the step mill has a revolving stair case with a fixed step height. Step mills require a dedicated power source, whereas the stair climber is self-powered.

Resistance Training Equipment

Resistance training equipment is a very important component of any home gym. There are all types of resistance training equipment for home use. The most popular types of resistance training equipment for home use are as follows:

- Free weights
- Rubber tubing and bands
- Bodyweight training systems
- Stability and medicine balls

Free Weights

Barbells and dumbbells are used in traditional single and multijoint exercises such as bicep curls and chest presses. Dumbbells take up varying amounts of space depending on the number of pieces, the type of storage rack, and the weight of the dumbbell. There are space-saving dumbbells that have varying weights that may be adjusted by a pin or knob.

Kettlebells are used in nontraditional resistance training. This form of resistance training can be used to increase cardiovascular conditioning as well as muscular power, strength, coordination, and proprioception.

Rubber Tubing and Bands

Rubber tubing and bands are very popular tools to increase muscular strength. They were originally used as physical therapy modalities and found their way into fitness centers and quickly into households. Tubing and bands come in varying resistances and lengths and can be easily stored and used in any space, making them a popular choice for individuals who have little or no space in their residence to exercise.

Bodyweight Training Equipment

Bodyweight training systems are an excellent modality of training for a home gym with little or no space allocated for resistance training. Rings and similar types of equipment can provide variable resistance with the use of gravity for total body resistance training. While increasing strength, bodyweight training systems will also improve total body stability, balance, and proprioception.

Balls

Stability balls are very popular tools for resistance training. Often, they are used in combination with other resistance training tools, such as dumbbells and medicine balls. This form of resistance training will increase an individual's strength, stability, coordination, and proprioception with the proper exercise prescription.

Medicine balls are great for dynamic resistance training and take up minimal space. Total body strength, power, coordination, and proprioception can be developed with the proper exercises. They come in variable sizes and weights.

Conclusion

Cardiovascular and resistance training equipment for home gyms can be space efficient and just as, if not more, effective as the equipment that can be found in fitness centers. Consulting with a fitness professional before purchasing equipment is prudent so that the equipment invested in is not contraindicated for the fitness goal of the individual investing in the equipment.

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Horse Riding, Injuries in

Injury is an inevitable consequence of the inherently dangerous sport of horse riding. Head and neck trauma are the most serious injuries and are frequently catastrophic. Helmets worn with a secure chin strap have been proven effective in preventing serious head injuries.

Epidemiology

Most serious equestrian-related injuries occur when a rider is thrown from the horse. Furthermore, injury may be incurred if the rider is then dragged or crushed by the animal. The two most common horse riding injuries are long bone fractures and head injuries. Head trauma is the injury most likely to result in hospitalization or death and is the most common career-ending injury for professional jockeys. The percentage of injuries causing death is higher in younger riders. Although most injuries are associated with the act of riding, approximately 15% of the injuries occur during nonriding activities such as shoeing and grooming. Hoof kick injuries to an unmounted rider represent about 30% of equestrian-related trauma.

There are several factors that contribute to making horse riding an inherently dangerous sport. The mounted rider's height, which places the average rider's head 12 to 13 feet (ft; 1 ft = 0.30 meters) above the ground, is by itself a major risk factor for injury. Good outcomes from riding activities, which can range from a slow-paced trail ride to competitive jumping over 6-ft gates at a fast canter, depend on the compatible pairing of two very different species. Factor in the animal's mass, strength, and speed (up to 40 miles/hour [mph; 1 mph = 1.6 kilometers/hour]), and the potential for a bad outcome becomes significant. Along these lines, the injury rates are especially high among event riders where successful jumping requires a coupling of considerable height and speed.

The majority of horse riding injuries occur during unsupervised leisure riding. However, experience in horse riding does not necessarily provide protection against injury, due, in part, to the inherent unpredictability of the horse–rider relationship.

Catastrophic Injury

Although the majority of horse riding injuries involve the extremities, the most catastrophic are those involving the central nervous system. Of the neurologic injuries, head injuries outnumber spinal injuries roughly by 5 to 1. Jumping is the equestrian activity posing the greatest risk for head and spine injury. The potential for catastrophic head injury in horse riding is directly related to the position of the rider coupled with the horse's speed. The head-forward stance, standard in racing and steeplechase, presupposes a significant increase in risk for head injury. Most head injuries in these scenarios occur as a result of the sudden acceleration-deceleration forces that occur with an unexpected fall.

At one extreme, the rider may be launched at high velocity in a projectile fashion, subsequently sustaining massive brain injury. More commonly, the rider will suffer a nonfatal concussion or cerebral contusion. Skull fractures most commonly occur when an unhelmeted rider is kicked. Among those seriously injured while grooming, the depressed skull fracture is the most common head injury observed.

Cervical fractures in equestrian sports tend to occur when a rider is thrown over the head of the horse unexpectedly and with such speed that there is insufficient time to protect himself or herself. As

A rider falls from his or her horse if it doesn't clear the hurdle. The most serious equestrian-related injuries occur when a rider is thrown from the horse. The two most common horse riding injuries are long bone fractures and head injury.

Source: Mikhail Kondrashov/iStockphoto.

result, the rider's neck is typically thrust into extreme flexion, which renders the cervical spine more vulnerable to fracture on impact. More commonly, the falling rider will respond to a fall with the natural protective mechanism of wrist, arms, and neck in extension. Considering the mechanism of injury, it is not surprising that roughly 50% of riders sustaining neck injury had concomitant head injury. A rider attempting to regain balance or to avoid falling risks catastrophic injury from pulling the horse down onto himself or herself. A significant number of horse riders with head and neck injury experience long-term disability.

Noncatastrophic Injury

Thoracolumbar fractures are the most common spinal injury seen in horse riding and are practically unique to the sport. The thoracolumbar junction (T12-L1 vertebrae) is the most common site of fracture. The injury is usually the result of a rider landing on his or her feet or buttocks subsequent to falling or being thrown.

Of the noncatastrophic equestrian injuries, overuse injuries are among the most common yet the least studied. Most overuse injuries in horse riders involve the shoulder, lower back, and lower extremities. Proper diagnosis and treatment of these injuries require knowledge of riding mechanics and the musculoskeletal demands placed on the rider. For example, the maintenance of balance and proper position at all times requires considerable strength and fitness of the lower back and thighs. The greatest forces during riding are absorbed through the rider's pelvis, sacrum, and lumbar spine. Because of this, maintenance of strong pelvic and core stability is the chief focus of most rehabilitative efforts. Equally important is a regular, balanced fitness program that incorporates postural training, routine stretching, and aerobic activity.

Injury Prevention

Current recommendations for the prevention of injury related to horse riding are fivefold and include the following:

1. Requiring helmet use on or near a horse.
2. Use of safety stirrups to prevent drag injury.
3. Matching the skill of the rider with the appropriate horse.
4. Providing close supervision of children and beginners.
5. Providing education programs primarily for novice riders, emphasizing the risks of riding and the methods employed to minimize them.

At present, the best standard for riding helmets is that established by the American Society for Testing and Materials (ASTM). To be fully effective, the helmet must be secured by a chin strap. Safety stirrups are designed to break away in the event of a fall in order to help prevent foot injury or trauma associated with being dragged. Wearing strengthened riding boots with heels, with emphasis on riding in "heels-down" position, greatly helps prevent the feet from sliding through the stirrup and potentially getting stuck.

Other general safety tips to consider include the following:

- When falling from a horse, try to roll to the side away from the animal.
- Do not ride if tired or under the influence of alcohol.
- Never walk behind a horse; it is always best to approach a horse at its shoulder as this is less threatening to the animal.
- The horse's ear movements provide important information about its demeanor. Ears that are pinned back indicate anger or apprehension of a threat.

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See also Head Injuries; Spinal Cord Injury

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Hydrotherapy and Aquatic Therapy

Hydrotherapy

Hydrotherapy is the immersion of the entire body or a body segment in water. Water immersion promotes an increase and/or decrease in superficial tissue temperature. The main goal of hydrotherapy is to decrease swelling, relieve joint pain and stiffness, and promote healing and relaxation.

Water has a number of physical properties, including buoyancy, viscosity, hydrostatic pressure, and a relatively high specific heat and thermal conductivity, that make it well suited for rehabilitation. There are many ways by which hydrotherapy may be implemented. Supplies include water and a "holder" such as the Hubbard tub for total body immersion and/or a whirlpool for a body segment. Bathtubs and buckets filled with water may also be used. Therapeutic hydrotherapy equipment has high-speed agitators that circulate the water to promote a massaging effect and relaxation.

Water temperature can be varied depending on the type and extent of the injury. In an acute injury, the water temperature should be cooler. In chronic injuries, the water temperature should be warmer. However, the water temperature should never exceed 105 °F. Hydrotherapy is indicated in the treatment of subacute or chronic traumatic and/or inflammatory conditions, muscle spasms, joint contractures, pain, muscle weakness, and alterations in peripheral conditions. Additionally, it can also be used for wound care and debridement. Some of the contraindications for hydrotherapy are uncontrolled seizures, unstable angina, uncontrolled diabetes, bowel incontinence, diarrhea, open wounds, bleeding, deep vein thrombosis, waterborne and kidney diseases, infectious diseases, and contagious skin rashes.

Some precautions for hydrotherapy are fever, infection, acute inflammatory condition, altered sensation, cardiac instability/hypertension, altered mental status, pregnancy, and communicable diseases. Abnormal responses to hydrotherapy include adverse physiological responses such as significant changes in blood pressure and respiration. Hydrotherapy should be discontinued as a treatment if the individual shows any adverse reactions or if the condition has resolved or there are no signs of improvement.

Aquatic Therapy

Aquatic therapy is a more specific type of hydrotherapy that must be delivered by qualified personnel. Aquatic therapy is used to restore function for persons suffering from acute, transient, or chronic disabilities, syndromes, or diseases.

The principles of water make it suitable for treating many conditions. The first principle, buoyancy, assists in supporting the weight of the individual, therefore decreasing weight bearing through the joints. By minimizing the stress placed through the joint, it is easier and less painful to perform exercises. This is especially helpful for individuals with weight-bearing restrictions, such as athletes recovering from surgery and/or a fracture. Water's viscosity provides resistance, which allows for muscle strengthening without the need for weights. When the resistance is coupled with buoyancy, strengthening muscles is easier with less joint stress. Aquatic therapy also uses hydrostatic pressure to create forces perpendicular to the body's surface. These forces decrease joint and soft tissue swelling, reduce spasticity, and also improve joint position awareness. This property is especially useful in sports medicine since it improves joint proprioception. Aquatic therapy is only performed in warm water, whereas hydrotherapy can be performed in either warm or cold water. The warmth of the water aids in muscle relaxation and promotes vasodilation of blood vessels, which increases the blood flow to the injured tissues.

Contraindications for aquatic therapy are the same as for hydrotherapy, though one must be especially careful as the whole body is typically immersed. Aquatic therapy can improve overall fitness and cardiovascular endurance, balance, and respiration. To obtain optimal benefit from hydrotherapy or aquatic therapy, one must take into account the risks and benefits of the treatment plan, the equipment selected, and the various means of applying hydrotherapy.

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See also Physical and Occupational Therapist; Principles of Rehabilitation and Physical Therapy

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Hyperextension of the Knee (Genu Recurvatum)

Genu recurvatum is defined as excessive backward motion during active knee extension. This "knee hyperextension" may be an isolated finding or part of a generalized multidirectional joint instability.

Prevalence

The prevalence of joint hypermobility affecting a few joints is substantial. One study showed that 18% of healthy subjects had at least one lax joint and 11% had three or more lax joints. The prevalence of generalized joint hypermobility varies from 10% to 30% and tends to decrease with age. Congenital genu recurvatum is a rare malformation with knee hyperextension and marked limitation of knee flexion at birth. This rare condition is thought to be caused by in utero positioning and genetic factors and can be treated with gentle manipulation, followed by serial splinting of the legs to achieve a more neutral position.

Symptoms

The major presenting complaint of children with hypermobility is pain. Less commonly, a parent or patient will complain of abnormal gait or apparent joint deformity.

Physical Examination

The patient should be observed while walking toward and away from the examiner. The patient should also be examined while standing still with the feet slightly apart and parallel (pointing forward). During these parts of the examination, excessive backward motion of the knee should be noticeable if the patient has genu recurvatum. The patient will also be examined for knee range of motion and joint stability while sitting and lying on his or her back.

Importance in Sports Medicine

Hyperextension of the knee or excessive backward knee joint mobility can contribute to recurrent knee dislocations. In severe cases, leg braces may be required to help support the knee joint and prevent injury.

Patients with hypermobility may present with traumatic and overuse conditions of the affected joint, which is the knee in the case of genu recurvatum. The patient may have a history of joint "swelling" that lasts for a brief period of time, complain of joint and muscle pain without any other apparent abnormality, or complain of symmetrical joint pain with use that is relieved by rest. Patients who are known to have hypermobility of the joints should be monitored closely during the athletic season and counseled about increased risk of injury during sports participation, especially high-contact sports such as American football, ice hockey, wrestling, and lacrosse. Furthermore, all patients presenting with new sports injuries should be thoroughly evaluated and assessed for evidence of hypermobility.

Later in life, osteoarthritis (OA) may be more frequent in older patients who have joint laxity. The presence of hypermobility in childhood, however, does not necessarily place that person at increased risk for OA later in life if his or her joint laxity has normalized with age.

Diagnosis

Genu recurvatum is easily diagnosed if hyperextension of the knee joint is present. The examiner should also assess the mobility of other joints, as some syndromes exist that involve hypermobility in multiple or all joints.

Treatment

Muscle strengthening is an important part of treatment and injury prevention for genu recurvatum. The use of individualized resistance exercise to quadriceps muscles is helpful. Referral to a physical therapist may be beneficial.

Symptomatic use of anti-inflammatory agents can be implemented. As mentioned above, severe cases may require braces for support and prevention of injury.

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See also Arthritis; Elbow Dislocations; Kneecap, Subluxating; Risk Factors for Sports Injuries; Shoulder Dislocation; Wrist Dislocation

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Hypertension (High Blood Pressure)

Systemic hypertension is the most common cardiovascular condition seen in competitive athletes as well as among adults in the general population. The diagnosis of hypertension is based on blood pressure levels persistently at or above certain levels as measured on two separate occasions. The primary concerns for the athlete with hypertension are the effect of exercise and competition on blood pressure control, or progression of hypertension, and the acute risk exercise and competition may pose to the athlete.

The Joint National Committee on the Detection, Evaluation, and Treatment of High Blood Pressure VII (JNC VII) has published guidelines and recommendations on the diagnosis and treatment of hypertension. These hypertension guidelines for adults over 18 classify prehypertension as systolic blood pressure (SBP) 120 to 139 mmHg (millimeters of mercury pressure) and diastolic blood pressure (DBP) 80 to 89 mmHg. Stage I hypertension consists of SBP 140 to 159 mmHg and DBP 90 to 99 mmHg, with higher readings indicating moderate to severe hypertension. In children and adolescents, hypertension includes repeated blood pressure measurements at the 95th percentile or higher, adjusted for age, height, and gender.

Diagnosis

Since the diagnosis of hypertension is based on blood pressure readings, it is important that the blood pressure be measured accurately. Measurements outside the office setting may be useful as a screening tool; however, diagnosis should be made only based on accurate, repeated office readings. The recommended method for office measurements is the auscultatory (listening) method with a properly calibrated and validated sphygmomanometer (blood pressure cuff). The athlete should be seated quietly in a chair for 5 minutes with arms resting at heart level and feet on the floor. The sphygmomanometer should fit properly, with the bladder encircling 80% of the arm to ensure accuracy. Avoidance of caffeine 1 hour prior to the reading and smoking 30 minutes prior to the reading is recommended. Two readings should be taken, separated by several minutes if possible, and there should not be variation of more than 5 mmHg between readings. If the initial values are elevated, then another set of two readings should be repeated after 1 week. The cuff should be inflated 20 mmHg above the SBP (identified by the disappearance of the radial pulse) and deflated at 2 mmHg/second. SBP is the point where the first sound is heard, and DBP is the point where the sound disappears. The blood pressure, patient position, arm used, and cuff size should be documented.

Effect of Exercise on Blood Pressure

Before they begin training, blood pressure should be accurately measured in all individuals interested in participating in competitive athletics. Hypertension is the most common primary diagnosis in America, with 50 million adults being diagnosed with it; only 34% of cases of hypertension are adequately controlled. The primary goal in treating hypertension is to reduce morbidity and mortality from complications of the disorder. Modifications such as weight loss, proper diet, limiting alcohol consumption, and increasing physical activity can be effective in lowering blood pressure. The American College of Sports Medicine's position stand on hypertension and exercise examines numerous studies that identify lowered blood pressure readings in patients on regular dynamic/aerobic exercise programs. The paper also described a drop in blood pressure lasting about 22 hours after an exercise session. Even modest reductions in blood pressure of 2 mmHg have been shown to reduce the risk of stroke by 14% to 17% and coronary artery disease by 6% to 9%. Additionally, the exercise benefits in hypertension were observed across a range of ages, between genders and among different ethnic groups. There are insufficient data in children and adolescents to establish a pattern of benefits with exercise and hypertension.

A moderate level of training intensity (40–70% maximal heart rate) had the same or a slightly higher benefit in lowering blood pressure compared with high-intensity training. As with any exercise program, a gradual increase in the level and intensity of activity is recommended, especially in the untrained individual. Resistance training has typically been discouraged in hypertensive patients as a result of studies that showed a dramatic and acute elevation in blood pressure during heavy-resistance/weight training. Reports of adverse events of stroke or heart attack precipitated by heavy-resistance training have also been published. However, studies examining the effects of long-term resistance training have failed to demonstrate any deleterious effects. Circuit weight training has been found in studies to have more blood pressure–lowering benefits than conventional weight training strategies. The combination of dynamic aerobic exercises with resistance training would provide optimal benefit in lowering blood pressure.

Evaluation

The continuous rise in the prevalence of childhood obesity leads to increasing concern about the development of hypertension. Lifestyle issues such as diet and level of physical activity contribute to the risk of developing hypertension. The school sports exam is a unique opportunity to address these issues and other risk factors such as smoking, alcohol use, and use of illicit drugs and anabolic steroids by the athlete. Any athlete with persistent hypertensive readings should have a complete history and examination done in order to develop an appropriate plan of evaluation and treatment. Lifestyle issues are clearly important, but possible underlying disorders must not be overlooked during the evaluation. Diagnostic studies should include an electrocardiogram (EKG), urine tests, and blood tests to assess blood counts, blood chemistry, cholesterol, and kidney function.

The majority of patients with hypertension have primary or essential hypertension with no identifiable cause. Patients with essential hypertension often identify other family members with high blood pressure, indicating positive family history as a risk factor for hypertension. In some patients, hypertension is the result of an underlying problem that needs to be identified and treated in order to adequately control the blood pressure. Causes may include sleep apnea, use of drugs or alcohol, kidney disease, thyroid or other endocrine disorders, and pheochromocytoma (a rare, hormone-secreting tumor). Children and adolescents with hypertension should be evaluated with particular attention to kidney disease and coarctation of the aorta (abnormal narrowing of the aorta), which are often the cause of hypertension in this age-group. A thorough history will identify the symptoms of the patient that would raise suspicion for the above problems. Careful and close monitoring of the hypertensive patient is essential since poor blood pressure control with treatment will also raise suspicion for these secondary causes.

Evaluation of target organ damage is necessary before a treatment plan can be recommended. Assessment of the heart for evidence of heart attack, thickening of the heart wall muscle, or heart failure will influence greatly treatment choices and recommendations for physical activity. The brain is susceptible to stroke, while kidney function may decrease due to the effect of hypertension on the blood vessels. The retina of the eye and the arteries in the legs can be affected as well. Thorough evaluation for these complications is necessary before making recommendations regarding exercise.

The benefits of exercise for blood pressure control are well documented. However, underlying coronary heart disease in the setting of vigorous physical activities could precipitate sudden death. Even mild hypertension is a risk factor for heart disease, making an assessment prior to participation in an exercise program clinically important. The nature of the pre-exercise evaluation is based on various factors, including patient age, underlying medical problems, and type and intensity of activity to be performed. Exercise testing could be considered but has been shown to be a poor predictor of sudden cardiac death. The American College of Sports Medicine has published guidelines to assist clinicians in assessing patient risk for sudden death. These guidelines are helpful in making appropriate exercise-testing recommendations based on the risk assessment plus the goals and objectives of the exercise program. Each athlete with hypertension requires an individualized assessment to outline the appropriate evaluation. Only then can the clinician make recommendations regarding the exercise program that is the safest.

Treatment

Untreated hypertension in the athlete may cause some limitation in exercise performance. Many of the medications used to treat hypertension may have undesirable side effects and may also affect exercise performance. Initial treatment should be directed toward lifestyle modifications such as change in diet and avoiding tobacco products and excess alcohol. High-risk behaviors such as use of illicit street drugs and performance-enhancing substances, such as steroids or growth hormones, have adverse effects on blood pressure.

Patients who are unable to achieve appropriate blood pressure control with lifestyle changes may require treatment with medications. Numerous classes of medications are available for the treatment of hypertension. Unfortunately, many of these medications may have physiologic effects or side effects that could adversely affect exercise performance. Diuretics may impair the body's heat regulation and may cause dehydration or muscle cramps. Beta blockers prevent increase in heart rate with exercise, which affects performance and also may worsen asthma. Both diuretics and beta blockers are banned by the International Olympic Committee doping organizations. Diuretics may mask other banned substances in the urine during drug testing, and beta blockers are able to diminish tremors and anxiety, creating an unfair advantage in sports such as archery and shooting.

All classes of medications may have effects on hemodynamics with exercise. The choice of antihypertensive agent for an athlete requires careful consideration of all these medication effects as well as the athlete's exercise goals.

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See also Beta Blockers; Diuretics; Doping and Performance Enhancement: A New Definition; Sudden Cardiac Death

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Hypnosis and Sport Performance

Hypnosis is a suggestive technique that has been used to help a person change thoughts, perceptions, sensations, or behaviors. The use of hypnosis for enhancing sport performance has enjoyed a steady increase over the past three decades. As athletes have recognized the importance of mental training techniques in their quest for excellence, effective interventions such as hypnosis have come increasingly into use. Although hypnosis has value if used properly in sports performances, it also has the potential for harm if applied inappropriately in sporting situations. This entry focuses on the characteristics of sports performers who can successfully be hypnotized, the ways hypnosis can be used effectively to empower sports performers, and the type of hypnosis thought to be most effective with the athlete population.

Characteristics of Hypnotic Subjects in Sports

Hypnosis is a psychological intervention that is often misunderstood by the general population, including athletes. Hypnosis consists of three distinct stages: (1) induction stage, (2) utilization stage, and (3) dehypnotization stage. Most sports performers are prone to trying any technique that is purported to enhance their performance, even if it can also be dangerous. Athletes are specially gifted physical specimens, but that attribute is far from the most essential characteristic that makes for an ideal hypnotic subject. The trait that influences a person to be an ideal candidate for hypnosis is suggestibility. Many authorities believe that approximately 95% of the general population can be successfully hypnotized. Strangely enough, most athletes are not easily hypnotized because, through experience and training, they learn to be guarded and untrusting instead of being open and receptive. Even though many sports performers express a willingness and desire to be hypnotized (because it is deemed to be a quick and effective process), initially athletes are not ideal subjects until they become educated concerning this technique and become more trusting. To facilitate learning the skill of being hypnotized, it is important for the hypnotist to debunk any myths surrounding hypnosis. Unfortunately, the "stage hypnosis" movement has served to reinforce these myths with all potential subjects, including athletes. Stage hypnotists usually do not have formal training in hypnosis and serve to perpetuate these myths. They are often very talented in the induction and dehypnotization stages but are lacking in ethical considerations during utilization. For instance, no person who uses hypnosis in clinical practice would use the stage for entertainment purposes. Sports hypnotists use this technique for the suggested aids in performance mentioned later in this article.

Empowering Sports Performers Through Hypnosis

Hypnosis has been used by sports performers in a number of different ways: (a) to receive more benefits from relaxation, (b) for controlling anxiety, (c) pain management, (d) for enhancing imagery, (e) to improve concentration, (f) for erasing a performance block, (g) injury rehabilitation, and (h) for ego strengthening.

Hypnosis and Relaxation

Many, if not most, hypnotists use fairly deep relaxation as an induction technique for entering a hypnotic trance. Naturally then, subjects surmise that hypnosis and relaxation are the same phenomenon, but this is inaccurate. Actually, the quelling of the active mind (relaxation) is a skill in itself and is a beneficial side effect that hypnosis seems to enhance. There are various forms of "active hypnosis" as well as passive hypnotic trances. It is even possible for an athlete to actively move in a hypnotic trance while performing. Also, there are various induction techniques that use active hypnosis as the most effective way to get the athlete to experience this state. For instance, an athlete could enter a trance and then actually perform or move to the rhythm of his or her event while in a trance state. This is a very powerful and effective way to mentally as well as physically practice a sport.

Controlling Anxiety and Arousal

Two of the most powerful factors that limit sport performances are the emotions of anxiety and arousal. As anxiety increases, the ability to focus effectively is greatly diminished. On the other hand, as arousal increases, the ability to focus narrows. These situations are crucial because most athletes experience anxiety and also need to reach an individual level of arousal to perform well. Hypnosis is beneficial in sports performance because it can contribute to creating a state of relaxation that mitigates anxiety. Also, hypnosis can be used as a technique to reach an optimal level of arousal prior and during competition. In other words, hypnosis can effectively train a performer "to be intense but not tense." This emotional balance is crucial for attaining great performances in sports situations. Suggestions can be made in the trance state for powerful emotional transitions. Suggestions made in the trance state are not questioned by the athlete and often last for long periods of time if the sports hypnotist uses posthypnotic suggestions.

Pain Management

The human mind has the unique ability to either recognize and feel pain or ignore it. While in a hypnotic trance, it is indeed possible to reach an altered state where pain is not felt at the conscious level. Since pain in sports situations is a common occurrence because of extensive physical exertion, athletes readily seek ways to eliminate or reduce the feeling of pain. Hypnosis trains the mind to ignore the feeling of pain. Hypnosis is so powerful that under this technique some athletes have been able to withstand surgery without anesthesia and remain fully conscious during the entire operation. The whole concept of "glove anesthesia" is a demonstration of pain management in a hypnotic state. The sports hypnotist must be very careful to always leave some pain awareness in the athletes so as not to induce complete anesthesia, which would be very dangerous and would increase the possibility of overreaching and injury.

Enhancing Imagery

For sports performers, the skill of imagery normally has two perspectives: (1) seeing (visualization) or (2) feeling (kinesthetics). Both of these perspectives of imagery are extremely important for high-level performers. One of the benefits of hypnosis is to experience "heightened awareness" in all the human senses. Sports performers use their senses in a variety of different ways so that simple posthypnotic suggestions can be employed to enhance or at least focus on the various imagery perspectives. Learning to ignore distractions, feeling more intensity, and reliving past events (regression) are examples of the use of hypnosis and its effecting competition with imagery. In fact, even an increased learning effect can be induced with hypnosis as athletes can remember more information and practice cues when in a trance state. This is a very effective way to do additional practice while away from the athletic area.

Improving Concentration

Being able to concentrate while in the appropriate attentional style and at the right moment is the secret to committing fewer performance errors. Sports performances require the athlete to be able to change attentional styles almost instantaneously and automatically. If an athlete has to stop and think about what to attend to, it is most likely too late to perform effectively. Again, heightened awareness is a benefit of hypnosis and allows a performer to focus more quickly and clearly. Through hypnosis training, athletes can learn to change attentional styles with minimal effort and precision effectiveness. The ability to focus is a crucial skill in athletic performances. Hypnosis has been proven to increase an athlete's ability to concentrate for longer durations and on the more appropriate cues.

Erasing a Performance Block

Performance blocks are frequently the result of overanalyzing or overthinking about a motor movement that has previously been made automatic. As soon as an athlete interferes with an automatic response, the rhythm of the response is disrupted, and this creates negative emotionality, which is very strong and contributes to the increased probability that the negative response will occur again. Hypnosis can be used to keep the mind focused on the correct response instead of worrying about the wrong one. Hypnosis can aid in putting the mind on "automatic pilot" instead of focusing on the particulars of an incorrect technique. The athlete's mind in a hypnotic state is unquestionably more susceptible to suggestion and, therefore, will move immediately to the subconscious suggestion for improved self-image and performance possibilities that may be blocked by the conscious mind.

Injury Rehabilitation

In addition to mitigating the pain associated with injury, hypnosis is useful in recruiting the mind's powers to aid in the rehabilitation process. An example would be having the mind (under hypnosis) focus on sending more blood volume to an injured area to aid in removing infected tissues or reducing swelling; then, the injured area will heal more quickly. Employing hypnosis techniques to attain long periods of relaxed states also helps the process of rehabilitation of an injury. Much research has supported the ability of a hypnotic trance to facilitate and accelerate the healing process for athletic injury as well as to reduce the fear of reinjury in the athletic population.

Ego Strengthening

Negative beliefs (fears) that interfere with ideal performances are often buried deep in the unconscious mind of the athlete. Under hypnosis, these fears can be reached and subsequently reduced. Once the fears are addressed and overcome, the ego is strengthened, which is a lasting benefit for future performances. The self-image is constantly being fed information in a conscious and unconscious manner. Self-talk or internal dialogue is an ongoing phenomenon. Hypnosis is a very valuable tool to aid in programming the mind in a positive way.

Building Confidence

After ego strengthening, athletes can again use hypnosis to help increase inner strength (self-confidence). By eliminating some of the detractors to being confident and then providing uplifting scenarios to work on, hypnosis helps sports performers to be more positive about themselves and their abilities instead of focusing on the negative.

Types of Hypnosis and Their Effectiveness

The two general types of hypnosis that are commonly used with sports performers are *hetero-hypnosis* and *self-hypnosis*. Hetero-hypnosis is facilitated by a hypnotizer, while self-hypnosis occurs when a person enters a trance without the help of another person. People respond to hypnosis in many different ways, and athletes are no different. With these thoughts in mind, most professionals who have used hypnosis with sports performers begin with hetero-hypnosis (to determine how suggestible a subject will be) and then eventually train the athlete to use self-hypnosis. This is ideal because self-hypnosis allows the use of hypnosis by the individual instead of waiting for the hypnotist to be available. It should be clear that hypnosis may not be the answer for all psychological issues in sports performers. It is also of great importance that hypnosis be used by properly trained and credentialed professionals only.

Keith Henschen and Richard Gordin

See also Arousal and Athletic Performance; Psychological Aspects of Injury and Rehabilitation; Psychological Assessment in Sports; Sports and Exercise Psychology

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Hyponatremia, Exercise-Associated

Exercise-associated hyponatremia (EAH) is a life-threatening body fluid imbalance in which the sodium concentration within the bloodstream is below the normal reference range for the laboratory performing the test. A low (hypo) sodium (natremia) concentration (generally under 135 millimoles/liter [mmol/L]) within the bloodstream can cause all the cells in the body to swell because of corresponding changes in osmotic pressure. Rapid swelling of the brain (cerebral edema) and lungs (pulmonary edema) due to low blood sodium concentrations can lead to seizures, coma, and death. Once a rare and singular phenomenon that was first reported in athletic events more than 20 years ago, the percentage of EAH cases has increased significantly over the past decade. For example, as many as 13% of marathon runners and 30% of ironman triathletes have finished competitive events with EAH, while at least five deaths have been reported in marathon runners to date.

Exercise-associated hyponatremia is an acute hyponatremia that occurs during or up to 24 hours after prolonged physical activity and has rapidly become the most common life-threatening complication of endurance exercise. Because the number of EAH cases is increasing at an alarming rate in a wide variety of sports, it is prudent that the public be thoroughly educated on this topic as well as on the most appropriate fluid replacement strategies that ought to be followed during prolonged physical activity.

This entry discusses the causes, risk factors, symptoms, diagnosis, treatment, and prevention of EAH.

Causes

In simple terms, low blood sodium concentrations are caused by either a *depletion* of sodium from excessive salt loss or by a *dilution* of sodium from excess fluid intake. Current evidence suggests that the majority of EAH cases are caused by sustained fluid intake beyond the body's capacity to excrete any buildup of excess fluid (dilutional EAH). Although excessive sodium loss through sweat and urine may contribute to the development of EAH, this particular mechanism appears less common. The contribution of sodium loss in the development of hyponatremia may become more significant in endurance events lasting over 24 hours in hot environmental conditions; however, more research is necessary to fully clarify the role of sodium losses in EAH. Therefore, it should be emphasized that EAH is primarily a salt imbalance from the *ingestion* combined with the *retention* of too much fluid rather than from the ingestion of too little salt. Recent evidence suggests that the body's main antidiuretic hormone (arginine vasopressin) is stimulated during exercise so that any fluid excess cannot be appropriately excreted. At rest, any body fluid excess can promptly be excreted, so fluid overload hyponatremia is unlikely in healthy subjects under nonexercising conditions.

Risk Factors

Recognized risk factors have been identified in athletes developing EAH. Athlete-related (internal) risk factors include excessive drinking behavior, weight gain during exercise, low body weight, being female, slow performance pace, event inexperience, and ingestion of nonsteroidal anti-inflammatory medications. Event-related (external) risk factors include high availability of drinking fluids, exercise lasting over 4 hours, and unusually hot or extremely cold environmental temperatures. Although none of these factors can conclusively predict the development of EAH, a constellation of such risk factors, combined with any sign or symptom of hyponatremia, warrants urgent blood sodium measurement at a nearby medical facility.

Symptoms

Early signs and symptoms of EAH include bloating, "puffiness," nausea, vomiting, and headache. These signs are, unfortunately, very common during and after exercise in athletes with or without low blood sodium levels. As the severity of EAH progresses, more serious signs and symptoms associated with lung and brain swelling include difficulty in breathing, confusion, disorientation, agitation, and involuntary leg movements as if the athlete was still exercising. Seizures, coma, and death may result when blood sodium levels drop too quickly or descend below critical individual levels. Hyponatremia is a medical emergency, and the presence of any of these signs or symptoms is an absolute indication to measure the blood sodium concentration.

Diagnosis

A diagnosis of EAH can be confirmed via a blood test measuring serum or plasma sodium concentration. Portable electrolyte (sodium, potassium, and chloride) analyzers now exist, so venous blood samples can be obtained and analyzed at the bedside within a few minutes. Any collapsed athlete who is breathing, has a regular pulse, but is not responding to supportive care should undergo immediate measurement of rectal temperature and blood glucose and blood sodium to rule out heat stroke, hypoglycemia (low blood sugar), or hypernatremia (high blood sodium), all of which can present with similar signs and symptoms as EAH.

Some athletes with blood sodium levels below the normal reference range do not report any adverse clinical signs or symptoms (asymptomatic). However, in general, the lower the blood sodium value, the more severe the manifestations of underlying brain swelling. The most important point to consider regarding the diagnosis and concomitant treatment of EAH is that the actual blood sodium level is not as predictive of the actual "severity" of EAH as the clinical signs and symptoms are. For example, some athletes with sodium values less than 125 mmol/L walk around without obvious clinical signs or symptoms, while other athletes with sodium values between 130 and 135 mmol/L may have very severe symptoms. Thus, the presence or absence of clinical signs and symptoms (especially those related to altered mental status) are more predictive of the severity of EAH than the actual numerical blood sodium value. Therefore, the clinical signs and symptoms should serve as the more important treatment guide.

Treatment

EAH is a medical emergency, where any delays in diagnosis or in the most appropriate treatment may be fatal.

Athletes with asymptomatic hyponatremia should be treated with oral fluid restriction until urination begins. Athletes with this "biochemical" diagnosis should be thoroughly educated on the signs and symptoms of EAH and instructed to seek urgent medical attention should these signs or symptoms appear.

Athletes with mild signs and symptoms of EAH (without altered mental status changes) should also be treated with fluid restriction until the onset of urination and the concomitant resolution of symptoms. The administration of intravenous fluids with a sodium concentration that is below normal blood sodium concentrations (less than 135 mmol/L or a hypotonic saline solution) should be absolutely avoided. Intravenous fluids containing the same sodium concentration as is present in the bloodstream (an isotonic saline solution) should be considered *only* if (a) the athlete is under close medical supervision of a physician familiar with treating EAH, (b) there are clear documented signs of dehydration (hypovolemic hyponatremia), and (c) the athlete cannot tolerate oral food or fluids containing high amounts of salt. Athletes remaining in a field medical setting with mild symptoms that do not improve with fluid restriction and/or continued inability to urinate should be transported to a medical facility for further evaluation and treatment.

Athletes with EAH and altered mental status should be treated with a small intravenous bolus of a solution containing more sodium than what is normally present in the bloodstream (a hypertonic saline solution). Administration of a small concentrated amount of hypertonic saline solution should rapidly reverse brain swelling and facilitate an increase in blood sodium concentration by stimulating urinary excretion of excess body water. Once a diagnosis of EAH with severe cerebral symptoms is verified, emergent treatment with hypertonic saline can be lifesaving. Critically symptomatic athletes, once stabilized, should immediately be transported to an emergency care facility.

Prevention

Since EAH is primarily caused by the ingestion *and retention* of too much fluid rather than from the ingestion of too little salt, it is prudent that athletes avoid overconsumption of fluids before, during, and after exercise. Athletes, coaches, and health professionals should be advised that the best hydration strategies to prevent fluid overload hyponatremia are to drink according to the dictates of thirst and monitor body weight to avoid weight gain during exercise. Athletes participating in prolonged endurance activity should expect to lose roughly 2% of their prerace weight as a normal consequence of endurance exercise. Because the body's main antidiuretic hormone may be stimulated more vigorously during a race scenario, it is important to note that drinking strategies that worked well in training under similar conditions may lead to weight gain and EAH during competition.

Sodium supplementation in the form of salt tablets, salty snacks, or sports drinks will not prevent the development of EAH, although some evidence suggests that such supplementation retards the rate of blood sodium decline in athletes who drink in excess. Athletes should be advised that drinking any palatable beverage to quench thirst is more physiologically sound than adhering to any blanket guideline, predetermined hydration schedule, or baseline body weight during training and racing.

An educational program warning athletes about the potentially fatal consequences of overzealous fluid consumption before, during, and after exercise, combined with limiting fluid availability along the race course, has led to significant decreases in the number of reported cases of EAH around the world.

Tamara Dawn Hew-Butler

See also Dietitian/Sports Nutritionist; Medical Management of an Athletic Event; Nutrition and Hydration; Running Injuries

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I

Ice Hockey, Injuries in

Ice hockey is a fast-paced contact sport played extensively in Canada, Europe, Asia, and the United States. The speed, contact, ice, encircling boards, and unique equipment, including sharp skates, a projectile puck, and long sticks, provide a unique set of risks for injury. Despite these risks, ice hockey has fewer injuries than most other popular team sports. Protective equipment, proper technique, adequate conditioning, and good sportsmanship are keys to prevention of serious injury.

The Game

In hockey, two teams compete to score points by moving a thick hard rubber disc called a puck into the opposing team's net. Games are played on a sheet of ice called a rink, which is surrounded by boards that help keep the puck in play. During normal play, each team has six players on the ice, consisting of three forwards, two defensemen, and a goalie. All players wear ice skates and use long, L-shaped sticks to advance the puck.

Although the exact origins of hockey are debatable, modern ice hockey dates back to the late 1800s. Professional ice hockey originated in the upper peninsula of Michigan and spread throughout Canada in the early 1900s. Today, ice hockey is a widespread sporting activity played at the youth, collegiate, Olympic, semiprofessional, and professional levels.

Demographics of Ice Hockey

According to 2008 USA Hockey data, there are 35,000 registered hockey teams and almost half a million registered hockey players in the United States. A small but growing number of players are female, with the number of registered female players in 2008 topping at 59,000. Organized teams span the age range from 6 years and under to 20 years and over. Overall participation in hockey remains steady. Regional data show a strong participation in large northern states, with residents of Michigan, Minnesota, and New York making up almost one third of all registered hockey players.

Injury Epidemiology in Ice Hockey

Data gathered from a variety of sources, including the National Collegiate Athletic Association (NCAA) Injury Surveillance System, the National Electronic Injury Surveillance System, and individual studies on sports injury epidemiology, show that ice hockey is among the safest collision sports and compares favorably with noncontact sports such as basketball, baseball, and soccer. Most of these studies take into account the fact that fewer people participate in hockey than in some of these other sports by representing injuries at a rate per 1,000 participants.

Despite the fact that hockey is relatively safe compared with other sports, several trends seen in the epidemiological analysis of hockey injuries are worth mentioning:

- Most injuries occur during games.
- Most injuries are due to contact with another player or the boards.
- Injury rates increase with increasing age of the player.
- Forwards have the greatest risk of injury and goalies the least.
- Injuries have decreased over the past 15 years corresponding to rule and equipment changes designed to improve the safety of hockey.

Specific Ice Hockey Injuries

Acute Traumatic Injuries

Head and Neck

Although the vast majority of injuries to the head are minor, these injuries can also be the most devastating in hockey. Cervical spine injuries are of the greatest concern. The mechanism of injury is typically a check from behind or a fall, causing head contact with the boards. Head injuries, including concussions, are relatively common and require medical management to prevent any complications. Eye injuries have dramatically decreased since the use of face shields but can be disabling when they occur. Laryngeal fractures and neck lacerations are exceptionally rare but catastrophic when they do occur. Neck guards have been recommended to decrease the chance of these injuries, but few data exist to demonstrate their efficacy. Dental trauma and facial lacerations are common and require immediate medical attention.

Lower Extremity

Lower extremity injuries are less common in hockey, but hip pointers or contusion to the hip and pelvic bone occurs from contact or collision. Groin strains are uniquely common in hockey, and although most resolve, they can become chronic, disabling conditions. Quadriceps contusions are a relatively common injury from collisions with other players and can result in significant time lost from sport. Knee ligament injuries are less common in hockey than in many other sports, but injuries to the medial collateral and anterior cruciate ligaments do occur and are typically caused by contact. Meniscal injuries can cause clicking and pain in the knee and can be seen in association with ligamentous knee injuries. High ankle sprains are seen more often in hockey due to the effect of the skate. Foot fractures can occur from impact with the puck or boards.

Upper Extremity

The upper extremity is the most common site of injuries in hockey. Sprains at the joints between either end of the collarbone are common in hockey and may cause pain, swelling, and deformity. Clavicle or collarbone fractures are also common and are typically associated with deformity, pain, and swelling over the middle of the collarbone. These injuries are often caused by a fall on the shoulder or a check into the boards. Shoulder dislocations are seen more commonly in older players and may result from falls on the ice or collisions. Fractures to the hand and wrist can be caused by slashing contact from the stick or falls on the ice. Injuries to the ligaments of the thumb can be caused by a fall on the ice with the stick in the hand, forcing the thumb away from the hand. Commonly known as “skier’s thumb” or “gamekeeper thumb,” these injuries can lead to chronic instability in gripping and pinching motions.

Trunk

Injuries to the chest or abdomen can lead to several serious medical problems, including lacerations or bruising of the spleen or kidney, or lung contusion.

Nontraumatic Injuries

Irritation of the tendons on the top of the foot from tight laces or ill-fitting skates can cause inflammation, a problem often called “lace bite.” Skin irritation and rash, or dermatitis, are commonly seen and are caused by mechanical irritation, bacterial infection, and accumulated moisture from sweating. “Sportsman’s hernia” can occur with chronic groin strains and involves injuries to the lower abdominal muscles. Tendinopathy of the wrist can result from frequent repetitive stick motions.

Prevention of Injury

Although hockey has many unique features predisposing to injury and a popular image as a rough, dangerous sport, the data show that it is safer than most other commonly accepted “noncontact”

An injured hockey player is attended to on the ice by the team doctor. Most injuries occur during games and are due to contact with another player or the boards.

Source: Joe Tomasone/iStockphoto.

sports. Prolonged skill development, appropriate competitive groupings, and adherence to the rules and recommended protective equipment appear to be crucial to the current safe state of hockey play.

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See also Protective Equipment in Sports; Shoulder Injuries; Skin Infections, Bacterial; Spinal Cord Injury

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Iliotibial Band Syndrome

Iliotibial band syndrome (ITBS) is an overuse injury seen most commonly in distance runners and other athletes whose sports require a great degree of knee flexion. ITBS, sometimes called *iliotibial band friction syndrome* (ITBFS), typically causes lateral knee pain that is insidious in onset. It is the most common cause of such knee pain in runners and accounts for up to 12% of running-related injuries. Diagnosis can be relatively straightforward, but ITBS is often very frustrating to treat, for both patients and clinicians.

Anatomy

The iliotibial band (ITB) is a tough, fibrous band of deep fascia that is extremely strong and rather thick. Proximally, the ITB originates at the iliac crest and then inserts distally at the Gerdy tubercle in the lateral tibia, as well as the patella and the biceps femoris tendon. The ITB, therefore, crosses two joints, the hip and the knee, and can be involved in pathology in both areas (e.g., the ITB is implicated in the development of some forms of "snapping hip" and in trochanteric bursitis).

The ITB appears to act as an anterolateral stabilizer of the knee, but its primary function appears to be controlling and decelerating the adduction of the thigh on heel strike during running.

The condition of ITBS is one of knee pain that results from excessive friction of the ITB over the lateral femoral epicondyle. At full extension, the ITB lies anterior to the femoral epicondyle; at about 30° of flexion, the ITB begins to traverse the femoral epicondyle as it moves posteriorly. With repetitive flexion and the associated friction, irritation of the ITB and underlying soft tissues can ensue.

The gross pathology and histopathology of the tissue involved in ITBS has been described from tissue obtained at the time of surgery and magnetic resonance imaging (MRI) evaluation. Changes in both acute and chronic inflammation have been found, confirming that ITBS is a true inflammatory condition (Figure 1).

Risk Factors for ITBS

Some observational studies have identified potential risk factors for the development of ITBS, including preexisting ITB tightness, high weekly mileage, training on a track, interval training, and muscular weakness of the knee extensors and flexors and hip abductors. Other authors, with less evidence, have noticed a possible association with the following: foot supination and compensatory pronation, running on hills (especially downhill) or on beaches, cycling seat height, anatomic factors (e.g., genu varus, tibia varus, heel varus, forefoot supination, and compensatory foot pronation),

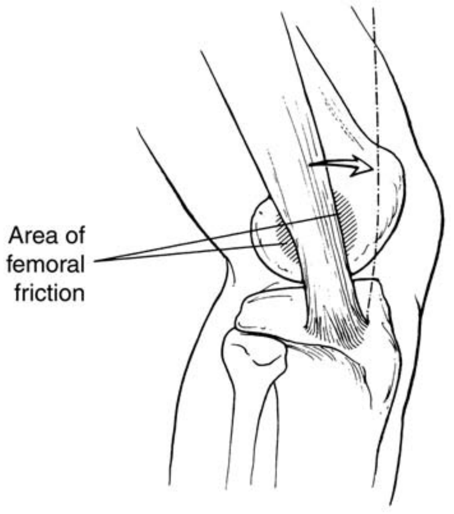

Figure 1 Iliotibial Band Syndrome

Note: Iliotibial band pain occurs where the band rubs against the lateral epicondyle of the femur.

tight hamstrings and tight quadriceps, and limb length discrepancies (ITBS typically develops in the shorter leg).

Risk factors are often divided into those that are "extrinsic" to the athlete (e.g., training techniques such as track running or equipment such as bicycle seat height) and those that are "intrinsic" (e.g., anatomic issues such as foot pronation or biomechanics such as hip abductor weakness). Both extrinsic and intrinsic risk factors can be targeted during treatment. It is incumbent on the astute clinician to identify these risk factors from the history and physical exam of the patient.

Presentation/Diagnosis

The history is usually one where the patient is able to identify no obvious macrotraumatic event. Most often the condition is found in runners; but it has also been described in cyclists, soccer and tennis players, skiers, and even weight lifters (e.g., those doing power lifting moves, such as squats). Lateral knee pain will have developed insidiously, and the athlete will typically complain of a sharp or burning pain approximately 2 to 3 centimeters (cm) proximal to the joint line that develops after a reproducible period of time or distance during a run or workout. Often the running athlete will specifically notice a worsening of the condition associated with running downhill. As the condition progresses, pain can develop earlier during a workout or may even occur during walking, particularly down stairs.

Further history taking should focus on identifying possible contributing extrinsic factors: If the patient is a runner, does he or she run on a track, on the beach, or on hills? Has there been a recent increase in training or a change in the training regimen?

The physical examination should not only focus on the knee but also include an analysis of the entire kinetic chain on the affected side. As always with lower extremity pathology, the clinician should ideally begin the examination with an inspection of gait. Is there an antalgic component to the gait? Does the patient's foot pronate or supinate? On one-legged stance inspection, is there a Trendelenburg sign? Is there a limb length discrepancy?

On focused examination of the knee itself, there should be no joint line tenderness or any significant effusion in isolated ITBS. Normal range of motion should be preserved. Palpation of the ITB, particularly over the lateral femoral epicondyle, may elicit pain. There may be localized swelling in the same area. Further palpation may elicit trigger points throughout the ITB as well as the vastus lateralis, and the distal ITB is often noted to feel ropy and thick. The vastus medialis obliquus (VMO) is often relatively underdeveloped.

Specialized tests include the Ober test, the Noble compression test, the Renee creak test, and the hop test.

The *Ober test* assesses ITB tightness and is performed with the patient lying recumbent on the unaffected side with the affected leg's hip and knee flexed slightly. The involved knee, which is off the table, is flexed to 90°, and the thigh is abducted passively and extended to catch the ITB over the greater trochanter. The thigh is then adducted passively. If the thigh remains suspended off the table, it indicates a shortened ITB.

The *Noble compression test* is a provocative test performed by having the patient lie on his or her side with the affected knee up and flexed to 90°; pressure is applied to the ITB overlying the lateral femoral epidondyle, and the knee is passively extended by the examiner; the test is considered positive if pain occurs as the knee approaches 30° of flexion.

The *Renee creak test* is a provocative test performed by having the patient stand on a step stool and then support all the body weight on the affected leg, allowing the unaffected leg to dangle over the edge of the step. The operator's thumb is placed over the lateral femoral condyle, and pressure is applied while the patient flexes the knee until about 30° by doing a one-legged squat. Reproduction of pain with this maneuver is considered a positive test for ITBS.

The *hop test* is another provocative test that is simple to perform. The patient is asked to hop up and down on the affected extremity keeping the knee flexed to roughly 30°; if this maneuver elicits pain, the test is considered positive.

The differential diagnosis the clinician should consider includes patellofemoral syndrome, stress fractures of the femur or tibia, discoid meniscus, lateral meniscal tears, fat pad syndrome, plica, politeus tendinitis, osteoarthritis, and lateral collateral ligamentous instability. A thorough history and physical examination are almost always sufficient to establish the diagnosis as ITBS and rule out other contenders. Plain X-ray films and MRI are occasionally necessary to evaluate other possible diagnoses. For ITBS itself, plain films would be expected to be negative, and MRI can show inflammatory changes in the area where the ITB crosses the lateral femoral epicondyle.

Treatment

Treatment consists of relative rest, controlling the inflammation, and addressing the underlying biomechanical factors, both intrinsic and extrinsic, that have contributed to the clinical scenario. Obtaining patient compliance is crucial to success.

The provocative activity should be avoided. Cross-training can sometimes be accomplished with swimming or pool running. As long as they remain painfree, flexibility and strengthening activities can begin promptly.

Inflammation must be controlled, and this is typically done with therapeutic dosages of nonsteroidal anti-inflammatory drugs (NSAIDs) and frequent icing. Occasionally, targeted steroid injections into the area of maximal pain can be used. One study has looked at the use of a local injection of 40 milligrams (mg) of methylprednisolone acetate and demonstrated good results. Some authors advocate injections as early as 3 days into the treatment period if other measures, such as rest, ice, and NSAIDs, have been unable to reduce the swelling and pain promptly. Physical therapists can use modalities such as cryotherapy, phonophoresis, and iontophoresis to control the inflammation.

The goals of physical therapy include targeted increases in flexibility and strength associated with some of the intrinsic factors contributing to the syndrome. Stretching the ITB, the hamstrings, and the quadriceps is vitally important. Strengthening the ipsilateral hip abductors, especially the gluteus medius and the ipsilateral vastus medialis, is also important. Almost all the exercises described in the literature listed in the Further Readings can be done without special equipment. The use of a hard Styrofoam (the trade name for expanded polystyrene) ITB foam roller (found in many gyms these days) for self-massage of the ITB is encouraged, as long as the user avoids direct pressure over the inflamed tissue.

Some patients will benefit from the correction of underlying limb length discrepancies and of foot biomechanics with devices such as heel lifts or orthotics.

The history and physical exam should give the clinician a good idea of what extrinsic risk factors have contributed to the onset of the syndrome and need to be addressed to prevent the return of symptoms. Bicyclists can often benefit from a custom fit of their bike; often, lowering the seat slightly is sufficient to avoid critical impingement of the ITB against the femur, which occurs at about 30° of knee flexion. Adjusting the foot position on the cycle pedals can be helpful as well. Runners should be encouraged to avoid running unidirectionally on banked surfaces (e.g., an indoor track, a beach, or a graded roadside). Avoiding intervals, track workouts, and hills and beginning at a lower mileage than pre-injury can be a good starting point for a runner to resume his or her training.

Conservative treatment is usually successful, though the condition can reoccur. Surgery is rarely necessary. Success has been achieved with a surgical procedure in which a triangular piece of the ITB is resected from the area overlying the lateral femoral epicondyle when the knee is in the critical position of 30° flexion. In one study, 84% of surgically treated patients reported good to excellent results. As with many acute and chronic inflammatory conditions, however, surgery should be considered as the last resort.

James Patrick Macdonald

See also Foot and Ankle Injuries, Surgery for; Joint Injection

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Imagery and Visualization

Imagery and *visualization* (terms often used interchangeably) represent a set of skills that are at the core of sport psychology interventions. Simply defined, imagery represents using one's mind to create images in multiple sensory modalities (hence making visualization somewhat of a misnomer), in an environment where one can relax, imagine excellent performance, adjust one's arousal or motivation level, and/or problem solve without ever leaving one's comfortable seated position. It is very similar to a real experience, and research has shown that parts of one's brain that are responsible for the actual movement of the body parts become active when engaging in imagery, similar to actually performing the task. In effect, imagery can be either a re-creation of past experiences or a simulation of what one will do in the future.

Modalities

As mentioned above, the terms *imagery* and *visualization* are often used interchangeably, but all of one's senses can be used to increase the vividness of one's imagery, and thus, it need not be limited to vision. Certain sensory images can readily bring the athletes to their sports arena: the golfer who smells the newly manicured greens, the gymnast who can feel the texture of the chalk on his or her hands, and the baseball player who recognizes the sound of a well-hit ball or the pop of the catcher's mitt. For athletes, the kinesthetic sense has the potential to increase the vividness of their imagery of engaging in sports activities. This is the sensation of where one's body is in space and how it feels while one is moving it. It appears that the more richly each sense is experienced and the more overall sensory experience the imagery contains, the greater the impact on the athlete.

Internal Versus External Perspectives

When an athlete imagines that he or she is actually participating in the sporting event and that he or she is either practicing or engaging in competition, it is referred to as the internal perspective, whereas the external perspective is when the athlete takes the role of an observer. He or she is "just watching" from the outside. Even if the athlete imagines that he or she is watching his or her own performance, as if seeing a replay on television, it is still considered an external perspective. Some research has pointed to internal perspectives being more helpful in generating kinesthetic feedback that could improve performance. However, there are differing opinions on this matter. There is no strong evidence that one modality or perspective is "better" than the other.

Though anyone can use imagery techniques, it has been shown that there is a fair amount of variability in one's ability to do so. How vivid the imagery is will be crucial to its effectiveness, and while some people are able to really engulf themselves in the experience as if it were happening in real time, there are some who have difficulty doing so. Similarly, there is also variability in one's ability to control what happens in one's imagery. For some individuals, it can be a perilous exercise that can lead to an increase in anxiety and, in turn, a decrease in their performance if they are unable to imagine perfect execution and are unable to solve problems to maximize performance while in their imagery. This is a critical message that should be remembered. Imagery can be a powerful tool, but not all tools work for all people with the same effectiveness.

Another cautionary note is the importance of asking permission before engaging in imagery exercises. When the sport psychologist or coach is guiding the imagery, it can be equated to walking around inside someone's mind, and the professional may stumble onto something unexpected. This is particularly true if the athlete has a history of trauma. Imagery exercises can result in dissociation. While the probabilities of this happening may be unknown, the risk is not worth ignoring simple precautions. Always explain to the athletes what imagery entails, how it works, and what you plan to work on with them. They should always have the ability to say "no," before or during the exercise.

Different Utilities of Imagery

Relaxation

It has been well established that to perform optimally one has to be able to balance one's arousal levels. Increased levels of anxiety and tension can affect an athlete's fluidity of performance; thus, the ability to relax is a very valuable skill, and imagery can be quite helpful in acquiring this skill. The ability to envision a peaceful, relaxing place is an excellent start to learning relaxation skills. Commonly, a beach scene or tranquil lake setting can elicit plenty of sensory images that lend themselves easily to a feeling of relaxation; again, the athlete should be allowed to dictate the pace and the details, but encouragement of multiple sensory modalities is advised. In these settings, imagery can be paired with diaphragmatic breathing and/or progressive muscle relaxation to provide a very powerful relaxing exercise. Learning to relax can then be fine-tuned by learning to modulate one's arousal to a workable level for the task at hand. Relaxation imagery can also be a valuable tool for athletes who have difficulty falling asleep.

Practice

Because imagery represents the opportunity to simulate athletic activity, it is the perfect place to practice. It doesn't require any equipment. It is not weather dependent. And it can be invoked at any time. In fact, like physical abilities, mental skills improve with increased practice, and athletes should be encouraged to practice on their own what they have learned about the use of imagery.

Imagery can be useful in building confidence and motivation, as well as improving performance strategy. Imagery provides an opportunity for athletes to imagine all the details that contribute to excellent performance. This is true whether they are learning new skills, trying to perfect skills, or trying to retain the skills they have previously learned. Athletes can improve their concentration by imagining themselves staying focused and ignoring distractions. They can build their confidence by imagining their success, which can carry over into their future performances. Athletes understand that if they can imagine something, it can be made to happen.

This idea should be approached with caution as well because imagining good execution does not necessarily translate into athletic success. For this reason, imagery represents not only a training opportunity to home in on the details necessary for optimal performance but also a training ground to solve the problems that arise due to in-competition adversities. Examples of this could include adapting to a breaking ball when the batter is expecting a fast ball, a sudden gust of wind that distracts the golfer during her backswing, the sudden heckling of a fan while the player is at the free throw line, or the running back who needs to cut back his run as the defense has read where the play is going and is in a position to tackle him for a loss. Athletes can practice their problem-solving skills and improve their "vision" by using imagery.

Emotion Management

Apart from management of anxiety (as described above) by using imagery as a relaxation skill, imagery can be used in many other ways for emotion management. For example, by eliciting different emotional states in an athlete (with the athlete's permission, of course), imagery presents an opportunity for the athlete to explore how different emotional states can affect his or her performance positively or negatively. For some athletes, imagery can provide an opportunity to "psych themselves up" and motivate them for competition. It can give an environment to work out one's fears about a particular competitor or venue. Imagery can also illustrate for the athlete how intense anger can interfere with problem solving, cognitive processing speed, impulsivity, and fine motor coordination without having an actual impact during competition.

Imagery During Injury Rehabilitation

Imagery provides an opportunity to practice when an athlete's body does not allow him or her to do so. It can be used to continue to "rehearse" and "practice" while injured, which can promote healing and reduce recovery time. Imagery can be effectively used to distract the athlete from pain and thus can be useful in pain management and tolerance building. When resuming one's prior level of activity and managing fears of reinjury (following, e.g., a serious skiing accident), imagery can provide a safe training ground. Sport psychologists using imagery techniques can be of great assistance to sports medicine personnel in injury rehabilitation. Other related areas that might lead sports medicine professionals to refer to sport psychologists for the incorporation of imagery in an athlete's treatment include recovery from body image disturbance, issues related to body dysmorphia, activity disorders, and treatment of career-ending injuries.

The uses of imagery in sports are quite numerous, and research has shown that it is not only one of the most commonly used mental skills but also one of the most effective.

Mitch Abrams

See also Psychology of the Young Athlete; Sport and Exercise Psychology

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Immune System, Exercise and

The interaction between the immune system and exercise is complex and not completely understood. As the body's defense mechanism against infection, the immune system plays an integral role on a daily basis in keeping both athletes and the general population healthy. Exercise can affect the immune system either favorably or unfavorably depending on the type, intensity, and duration of the activity. It is widely accepted that upper respiratory tract infections (URTIs) are a major reason for poor performance in competitive athletics. Many of these athletes have been training at a high level in the preceding weeks, which may contribute to the lowering of their body's resistance to infection. Recreational athletes may also suffer from URTIs following episodes of heavy or unaccustomed exercise bouts. Understanding the impact of exercise on the immune system and its role in health maintenance will ultimately lead to better sports and work performance.

The Immune System: Innate and Adaptive

A full appreciation of the complex interactions between the environment, training, infection, and the immune system requires an understanding of the basics of immune system function. The immune system is made up of two complementary defenses—the innate immune system and the adaptive immune system. The innate system is a collection of mechanisms that are the body's first-line defense against potential pathogens, or infection-causing agents. These include the skin and the mucous membranes, which are physical boundaries against invasion. However, not all portals of entry into the human body are protected by the skin. These sites, including the nasal passages and oropharynx, are equipped with special mucus, enzymes, and complex proteins that immediately start the breakdown process of unwanted pathogens. The innate system begins the process of activating the inflammatory response, which is an important sequence of events leading to the four classic signs of inflammation: rubor (redness), calor (heat), tumor (edema), and dolor (pain).

While the innate immune system is predictable and mechanical, the adaptive immune system is more involved and complex. This is largely due to the mechanisms that allow it to remember specific pathogens and subsequent inflammatory responses. Having "memory" enables the adaptive system to recognize a certain pathogen that it has already been exposed to and quickly mount an immune response on reexposure. This process is carried out through three mechanisms. The first entails recognizing specific proteins on cell surfaces, called *antigenic markers,* that signify specific pathogens. After recognition, the adaptive system is capable of a cellular and molecular attack against that specific pathogen. Finally, with subsequent repeat attacks from those same pathogens and their associated cell surface proteins, the body's memory system can mount an accelerated response to ensure a balanced immune response and maintenance of health.

Exercise and Immune System Function

The impact of exercise and training on the immune system has been a topic of great interest over the past couple of decades. Many of the currently accepted principles have been developed over this time period. Research is certainly ongoing and evolving in this relatively new field of sports immunology. As exercise grows as a cornerstone of health promotion and disease prevention, it is increasingly important to understand the interaction of exercise and the immune system. Furthermore, as URTIs are appreciated as a contributing factor to poor sports performance, as well as a frequent cause of absenteeism in the workplace, more research is necessary.

According to recent research, the intensity level of training is a primary predictor of immune system function. Studies have shown decreased levels of an important immune protein found in mucosal secretions, called *immunoglobulin A* (IgA), after intensive training. This secretory immunoglobulin is partially responsible for combating infections encountered at the mucosal barrier of the upper respiratory tract. Lower levels of IgA in mucosal secretions put the body at an increased risk for URTIs. These decreases in IgA levels can occur after as little as 1 hour of vigorous exercise, which is often classified as 70% to 80% of aerobic capacity. While high-intensity exercise may put the athlete at an increased risk for URTIs, studies have also demonstrated significantly higher levels of IgA in those participating in regular, moderate exercise. This may give credence to the belief that a moderate amount of physical activity strengthens the body's ability to fight off infections.

Two other types of cells in the immune system are affected by physical activity. The function of natural killer cells, or *NK cells*, is enhanced by intensive exercise. NK cells are part of the innate immune system and help fight off viral infections and aid in the destruction of tumor cells. They perform this by secreting enzymes that destroy the target cells by a process called *apoptosis*, or programmed cell death. A second important component of the innate immune system, the *neutrophil*, appears to exhibit decreased functionality with increased intensity of exercise. The *neutrophil*, also known as a white blood cell, is the primary cell type in the body responsible for attacking infections and foreign materials. A decrease in neutrophil count and function has been demonstrated when comparing sedentary individuals with highly active individuals. Suppression of neutrophil activity likely plays a role in increased URTIs in athletes who are involved in high-intensity training.

Interest in the interaction between exercise and cancer prevention has sparked more than 100 retrospective, population-based studies. Overall, the evidence seems to indicate a significant reduction in colon and breast cancer in those participating in regular, moderate physical activity. When compared with sedentary populations, even low-intensity activities, such as mowing the lawn, seem to modestly reduce cancer rates. Survivors of breast or colon cancers may see up to a 40% relative risk reduction in terms of cancer recurrence and cancer-related deaths. Since the specific mechanisms behind the etiology of these benefits are not well understood, further research is ongoing in this intriguing field.

Another population whose immune system benefits from regular physical activity is the elderly. As the human body ages, it becomes more susceptible to infections, caused by slower and less potent responses to attacks, leading to longer recovery periods. The first layer of defense, the skin and mucous membranes of the innate system, can become broken down and permeable. Specific immune system cells, such as the T cell, often become less responsive to activation. These cellular deficiencies, coupled with other factors involved in normal aging, such as deconditioning, comorbid medical conditions, psychological stress, and nutritional deficiencies, all lead to a dysfunctional immune system. Regular physical activity becomes an important component of the health maintenance strategy for the aging population. For example, weight-bearing exercises can help mitigate bone demineralization, which results in osteoporosis, as well as supporting healthy immune function.

Since many highly trained athletes do encounter untimely URTIs that may be caused by suppressed immune system function, effort has been placed in attempting to find nutritional supplements that might enhance immune system function. The evidence for efficacious use of vitamins or minerals in excess of the recommended daily amounts is sparse. Vitamin C, at 600 milligrams (mg) daily for 3 weeks, does appear to have some benefits in reducing the occurrence of URTIs in athletes training and competing in ultra-endurance events. This is believed to be due to its antioxidant properties, which help reduce the free radicals produced by the oxidative stress related to prolonged intense training. Further research is ongoing on vitamin C and its effect on the immune system. Other studies investigating supplements such as vitamin E and betacarotene have not shown any benefit in terms of immune system support. A well-rounded diet is still the recommendation for most athletes, with increases in caloric intake during high-intensity training. A simple multivitamin can be added to the diet, but excessive intake of specific nutrients should be avoided in general.

Knowledge gained from analyzing athletes' immune system function during and after strenuous training can be applied to the clinical setting when deciding on how to treat URTIs. Infectious symptoms in an athlete should be evaluated in the same manner as in the general population, but one should also take into account each individual's circumstances. If an athlete is in the midst of intense training and near his or her maximal efforts, one should contemplate being more aggressive in treating potential bacterial causes of URTIs with antibiotics. Common primary care medical practice demonstrates that most URTIs are viral in nature and do not respond to antibiotics. However, depressed IgA levels in mucus and secretions may place athletes at an increased risk for bacterial causes of infections. Recent studies have also demonstrated possible anti-inflammatory effects of some classes of antibiotics, such as macrolides and fluoroquinolones, in URTIs, which may be responsible for the benefits of these medications independent of their antibacterial effect. Also, the close proximity of athletic teams, drinking from common fluid sources, dormitory living, frequent traveling, and time spent in locker rooms may also raise the risk of transmission of infections. Furthermore, high levels of stress and anxiety, as one might endure during competitive athletics, have been previously demonstrated to impair immune system function, placing the patient-athlete at increased risk of infection. Certainly, each athlete's situation should be examined independently and critically so as not to overuse antibiotics, which can perpetuate bacterial resistance. One cannot overemphasize general hygiene principles, including regular showers, not walking barefoot, timely and appropriate skin care, and adequate sleep and nutrition.

Conclusion

In summary, the athletic population is at an increased risk for infections, especially URTIs, during times of high-intensity training. However, and perhaps more applicable to the recreational athlete and the general population, mild to moderate aerobic activity may help enhance the immune system. It may be prudent to recommend moderate exercise as a part of overall health maintenance as it specifically relates to improved immune system function. While the supplement business is thriving, so far only vitamin C has demonstrated positive effects in the treatment and prevention of infections in athletes. Emphasis on a well-rounded diet, adequate sleep, and productive stress management should be part of athlete education at all levels.

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See also Carbohydrates in the Athlete's Diet; Infectious Diseases in Sports Medicine

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Infectious Diseases in Sports Medicine

Athletes are susceptible to illness due to close interpersonal contact, intense physical and emotional demands, and/or environmental exposures. Some infections have specific return-to-play criteria. This entry discusses common infections in the athletic population, their treatment, and guidelines for the sometimes challenging decisions on when an athlete may return to play.

Upper Respiratory Tract Infection

The term *upper respiratory tract infection* (URTI) encompasses a wide range of syndromes involving the nose, throat, and respiratory tract above the oxygen-exchanging alveoli. This section focuses on the common cold, influenza, and pharyngitis.

Viruses are the typical culprit in these infections, but the practitioner must be aware of bacterial presentations. These include bacterial sinusitis, strep throat, bacterial superinfections, and lower respiratory infections. The virus is spread by aerosols and droplets as well as by direct and indirect contact with the saliva of an infected individual. A large number of studies evaluating the influence of exercise on the immune system have been done. Evidence to date advocates moderate exercise as an immune protector, decreasing the risk of developing an URTI, while heavy, strenuous bouts of exercise increase the risk of infection due to negative effects on the immune system. Carbohydrate replacement before, during, and after exercise has been reported to assist in immunity maintenance. There are no definitive guidelines on returning the athlete to play. These determinations are based on returning the athlete safely based on his or her symptoms and not placing other athletes at risk.

Common Cold

The prevalence of the *common cold* is exactly as the name implies—common. It is a viral URTI caused by any of more than 200 viruses, the most common being rhinovirus, coronavirus, and respiratory syncytial virus. It is the most common cause of acute illness in the U.S. population and is responsible for the greatest number of missed days from school or work. It is spread via droplets in the air released when an infected individual coughs, sneezes, or talks. It is also spread by hand-to-hand contact when infected secretions contaminate an individual's fingers or hands and he or she then touches the eyes, nose, or mouth. Further transmission occurs via shared objects. Interestingly, studies have shown that person-to-person transmission depends on the amount of time people spend together and the amount of viruses shed by the infected individual. Viruses may survive on the human skin for up to 2 hours. Viral URTIs can result in secondary bacterial infections, causing sinusitis and pneumonia. The practitioner is faced with discerning the common cold from other, more serious infections and advising treatment and return to play.

Clinical Presentation

Athletes may complain of low-grade fever up to 102 °F, runny nose, congestion, sneezing, a sore throat, a mild to moderate hacking cough, and slight muscle aches and fatigue. The nasal discharge may become thick in consistency and change to yellow or green.

Diagnosis

The diagnosis is confirmed by patient history and symptoms. The physical exam findings are few in comparison with the patient symptomatology. Blood work rarely yields any useful information.

Treatment

Viral URTI is a self-limiting syndrome that can last from 5 to 14 days. Therapy is usually aimed at relieving symptoms. Antibiotics treat bacterial infections and are not indicated in viral infections. Congestion therapy includes hydration with water, juice, tea, or sport drinks to prevent dehydration and break up the thick mucus. Nasal decongestants come in oral form and nasal sprays. Oral decongestants commonly contain pseudoephedrine, which can have a stimulant effect and increase the heart rate and blood pressure and result in insomnia. Nasal sprays have a direct effect on the nasal mucosa, with fewer systemic side effects and a quicker onset of action than oral medication. These agents typically contain oxymetazoline. They are to be used for no more than 3 days due to the increased risk of rebound nasal congestion once the product has been discontinued. Antihistamines have been shown to reduce symptoms of runny nose and sneezing during the first 2 days of the cold. Vitamin C in 1 gram (g) or more daily dosing has been shown to produce 15% fewer symptomatic days per episode. Zinc may reduce the duration of cold symptoms. Over-the-counter cough suppressants such as dextromethorphan and expectorants such as guiafenesin may be used for dry, hacking coughs. The American College of Chest Physicians does not recommend over-the-counter cough syrups or cold medication in children younger than 14 years. Tylenol and nonsteroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen may be used for pain relief. Saltwater gargles are useful for sore throats. Aspirin should not be given to children due to the risk of Reye syndrome. It is vital for athletes to be aware that some over-the-counter preparations and supplements may contain banned substances.

Return to Sports

The decision to return an athlete to play is made on a case-by-case basis. Athletes may return to mild to moderate exercise with mild symptoms of the common cold. Some advocate using the "neck-check" criteria, whereby symptoms below the neck may preclude return to play. The American College of Sports Medicine recommends return to intensive exercise when an athlete is free of symptoms such as fever and muscle aches for several days.

Prevention

Good hygiene and social behaviors are essential in the prevention of the common cold. The infected athlete should cover his or her nose and mouth with a tissue when coughing or sneezing and then throw the tissue in the trash. Hand washing with soap and water or using an alcohol-based hand cleaner prevents the spread of the infection. It is important to avoid close contact with infected people by having them either stay at home or not participate in sport. Individuals should avoid touching their eyes, nose, or mouth.

Influenza

Influenza, also known as the flu, is a respiratory illness caused by the influenza virus that results in mild to severe illness. According to the Centers for Disease Control and Prevention (CDC), 5% to 20% of the U.S. population gets the flu each year, with 200,000 hospitalizations and 36,000 deaths. Its presentation can be similar to the common cold. The flu is spread via the same mechanism as the common cold (aerosols released by coughing or sneezing, touching the infected surfaces and then touching the mouth or nose, and so on). Risk of transmission is between 1 day before the development of symptoms and up to 5 days after. Pulmonary function can be diminished for up to several weeks in athletes with the flu.

Clinical Presentation

Influenza can present very similarly to a typical viral URTI; however, its symptoms are usually more severe. The onset of illness is typically abrupt. Fever ranges from 100 to 104 °F and may be associated with chills. Sore throat is a common complaint that may bring the patient to the practitioner for evaluation. Muscle aches range from mild to severe. Headache is common. Runny nose ranges from mild to severe. Severe fatigue and weakness may prevent the athlete from playing. Nonproductive cough and chest pain progress as the infection evolves. Children are more likely than adults to have gastrointestinal effects such as nausea, vomiting, and diarrhea.

Diagnosis

Diagnosis of influenza A or B is typically clinical but may be confirmed by nasopharyngeal or throat swabs that are sent for culture. The results may take 3 to 7 days to come. Recently, the Food and Drug Administration (FDA) approved three office tests for influenza, including the QuickVue. However, the cost and time restraints of these tests make clinical diagnosis of influenza preferable.

Treatment/Prevention

There is a saying, "An ounce of prevention is worth a pound of cure." The CDC has developed a brochure, titled "An Ounce of Prevention," advocating good hygiene in the prevention of spreading and/or contracting of infection. Actions such as covering the nose and mouth with a tissue while sneezing or coughing and then throwing the tissue away, washing hands with soap and water or using an alcohol-based cleanser, and keeping surfaces sanitized are all important. Teams should be vigilant for the onset of illness among teammates to initiate prevention.

Influenza is unique in that it has a vaccine to assist in prevention. The vaccine comes in two forms, a shot and a nasal spray. The shot is made from inactivated or killed viruses and can be used in individuals who are healthy, those older than 6 months, and those with chronic medical conditions. Typical side effects include soreness at the shot site, low-grade fever, and muscle aches. The nasal spray FluMist® is made from live, attenuated viruses or weak viruses that do not cause the flu and is used in nonpregnant individuals 2 to 49 years old. Side effects in adults include runny nose, headache, sore throat, and cough. In children, they include runny nose, wheezing, headache, vomiting, muscle aches, and fever. Antibodies develop that protect against influenza approximately 2 weeks after the vaccination. The vaccination period typically begins in September and may be continued through January or later. Influenza tends to peak in January. Winter teams are more susceptible to outbreaks and need vaccinations.

Note: Individuals who should not be vaccinated without first consulting a physician include the following:

- People who have a severe allergy to chicken eggs
- People who have had a severe reaction to an influenza vaccination
- People who developed Guillain-Barré syndrome (GBS) within 6 weeks of getting an influenza vaccine
- Children less than 6 months of age (influenza vaccine is not approved for this age-group)
- People who have a moderate to severe illness with a fever (they should wait until they recover to get vaccinated)

Antiviral influenza treatment is used to reduce symptom severity and duration and for prevention in people who have come in close contact with an infected individual and who were unable to receive the vaccine or in whom the vaccine was ineffective. Daily prophylaxis has been studied and supported in the prevention of outbreaks in nonvaccinated teams for 2 weeks after vaccine administration. Anti-influenza drugs include oseltamivir and zanamivir. These medications should be used within 2 days of symptom onset and for 5 days to shorten the duration of illness by 1 to 2 days and to decrease risk of transmission.

Pharyngitis

Pharyngitis, or sore throat, is responsible for 19 million clinic visits annually in the United States. Viruses are responsible for 50% of pharyngeal infections. Pharyngitis is a common presenting symptom for mononucleosis (mono), which will be discussed in the next section. Other implicated viruses include rhinovirus in the common cold, influenza virus, parainfluenza virus, herpes simplex virus, and human immunodeficiency virus. The cause of bacterial pharyngitis differs between adults and children. Group A β-hemolytic streptococcus (GABHS), or strep throat, is the most common cause of bacterial pharyngitis in children. Adult bacterial pharyngitis is caused by GABHS and other bacteria such as *Mycoplasma pneumoniae* and *Chlamydia pneumoniae*. Sexually active adults should raise the practitioner's suspicion for a gonococcal infection. Transmission is mainly through respiratory secretions but can occur via contact with food and fomites. The swelling may cause airway obstruction and/or inhibit the athlete from ingesting fluids, resulting in severe dehydration. GABHS pharyngitis that goes untreated may lead to rheumatic fever and kidney complications.

Clinical Presentation

The most common complaint is a sore throat worsened with swallowing that may radiate to the ears. Athletes with viral pharyngitis may have cough, runny nose, conjunctivitis, muscle aches, headache, pain with swallowing, and low-grade fever. Patients with the common cold tend to complain of a "scratchy" throat. On exam, viral pharyngitis presents with tonsillar swelling, redness, and/or exudates. Herpes pharyngitis is characterized by painful vesicles or shallow ulcers on the palate, lips, or mucosa. Bacterial pharyngitis clinically appears similar to viral pharyngitis, with tonsillar or pharyngeal swelling, redness, and exudates, but typically causes a fever of 38.3 °C or higher and tender anterior cervical lymph nodes and is marked by the absence of cough and runny nose. A sandpaper-like rash may develop over the chest and abdomen of individuals with GABHS pharyngitis.

Diagnosis

The rapid strep test is the first-line test for potential strep throat. Throat cultures take 24 to 48 hours to provide results and may reveal other pathogens. The mono spot test is discussed in the section on mono.

Treatment

Treatment is aimed at symptomatic relief in most cases of pharyngitis. NSAIDs reduce sore throat symptoms. Other treatments include saltwater gargles, throat lozenges, and hot soups or tea with honey. GABHS pharyngitis should be treated with an antibiotic to prevent complications, minimize spread, and shorten the duration of illness. Athletes with suspected or confirmed GABHS pharyngitis are no longer considered contagious after 24 hours of antibiotic therapy. Athletes may return to play if they have no systemic symptoms or fever.

Mononucleosis

The athlete and the general population are at equal risk of contracting *infectious mononucleosis* (mono). Mono is a viral illness caused by the Epstein-Barr virus (EBV), a member of the herpes virus family. The majority of infections occur in adolescents and young adults. The so-called kissing disease is transmitted via human saliva and secretions. Some patients may take up to 3 months to return to the premono level of activity. Serious complications have been reported in 5% of patients with mono. These include severe pharyngitis creating airway obstruction and splenic rupture in contact and collision sports.

Clinical Presentation

An athlete may present with the classic triad of fever, sore throat, and swollen lymph nodes. Fever typically does not go above 40 °C. Pharyngitis occurs in 80% of patients with mono. Again, it is important to remember that multiple other infectious agents, such as other viruses, strep, gonorrhea, and HIV, can cause sore throat. More than 50% of patients with mono have pharyngitis, with an overlying film that is white, gray-green, or necrotic appearing. Palatal petechiae, or pin-point–sized red dots under the surface of the tissue, are found in 25% of the patients. Swollen lymph nodes typically occur in the posterior cervical chain and can be found in the axilla and/or groin as well. The lymph nodes are large and resolve after 2 to 3 weeks. Further symptoms include headache and malaise. A rash on the upper extremities and trunk is present in 10% to 40% of patients. A rash may develop in patients treated with amoxicillin and ampicillin. It does not represent a true allergic reaction. An enlarged spleen, referred to as *splenomegaly*, occurs in 50% to 100% of patients with mono, posing the risk of splenic rupture. Studies have shown the clinical exam not to be a reliable indicator of an enlarged spleen, but when an enlarged spleen is suspected, typically the practitioner is correct. Athletes may present more of a challenge due to their developed musculature and/or size.

Diagnosis

Diagnostic studies typically start with blood work. This includes a complete blood count (CBC) and differential to evaluate for atypical lymphocytosis as well as a heterophile antibody latex agglutination test (Monospot test). A diagnosis of infectious mononucleosis (IM) is supported if an absolute and relative lymphocytosis is present with greater than 10% atypical lymphocytes on peripheral blood smear and a positive test for EBV. The heterophile test has a higher false-negative rate during the first week of illness, which declines in the second and third weeks. If the patient is early in the course of the disease and the monospot test is negative, it may be prudent to perform specific antibody tests. These reveal either primary acute infection or recent (within 3–12 months) infection by analyzing the pattern of IgM and IgG antibodies. Liver function tests should also be performed given that these are elevated in approximately 90% of individuals with mono.

Radiographic imaging, such as ultrasound and computed tomography (CT scan), has not been advocated for assessing the size of the spleen. There is variability in the size of the spleen among individuals, with men having larger spleens than women. A single spleen measurement is not predictive of splenomegaly or risk of rupture. Furthermore, data have not shown a correlation between splenic size and risk of rupture.

Treatment

Mono is a self-limiting disease. Supportive treatment focuses on symptomatic relief, including rest, hydration, and NSAIDs for fever or pain. Isolation is not indicated given the low transmissibility of EBV. Adolescents should not be given aspirin, because of the small risk of bleeding and low platelet count. Mono's effects on the liver necessitate caution with substances such as alcohol, acetaminophen, and other liver-toxic compounds. Corticosteroids such as oral prednisone are indicated in patients with upper airway obstruction, significant tonsillar hypertrophy, severe sore throat causing inability to swallow, splenic enlargement, inflammation of the heart known as *myocarditis*, low platelet count, or *anemia*. Antiviral agents are not recommended in uncomplicated EBV infection. Neither steroids nor antiviral agents have been shown to reduce time to return to play. Rest over a 2- to 3-week period is recommended given that exertion increases the risk of splenic rupture and the first 3 weeks have the greatest risk of splenic rupture. Patients who are suspected of having splenic rupture should be evaluated in the emergency department with access to acute surgical evaluation.

Return to Sports

No well-designed large clinical trials have been performed to help develop guidelines on when the athlete is allowed to return to play. Current literature supports focusing on symptom resolution and absence of splenomegaly. The athlete may return to light, noncontact activities 3 weeks from symptom onset, with a gradual progression of activity. The risk of splenic rupture is greatest in the first 3 weeks, with cases having been reported up to 7 weeks. Radiographic imaging is not always recommended given that a baseline and serial measurements are necessary to evaluate the normal value in a specific individual. The athlete should be educated on the risk of splenic rupture and should understand that physical exam is not a reliable tool. Return to contact activities should be at least 3 weeks from symptom onset and should correlate with the athlete being free of symptoms with a normal level of energy.

Cutaneous Infections

As discussed in the previous section, skin-to-skin contact is an effective mode of transmitting infections involving the skin. The term *gladiatorum* has been used in describing cutaneous infections contracted during activity. The major players in these infections are viruses and fungi. The provider must be able to recognize these common infections in order to treat them and prevent their spread among teammates.

Bacterial

Methicillin-Resistant *Staphylococcus aureus* (MRSA)

Staphylococcus aureus is a bacterium present on the human skin that is responsible for many skin and soft tissue infections. It is found in the nose of

30% of healthy, asymptomatic people and in 65% of people with staphylococcal skin infections. Methicillin-resistant *S. aureus* (MRSA), once considered a hospital-acquired pathogen (HA-MRSA), is a strain resistant to specific antibiotics in the penicillin and macrolide family. A new strain has emerged in the past decade in the general population, referred to as *community-acquired MRSA* (CA-MRSA). It is manifested in healthy individuals as skin and soft tissue infections. It commonly occurs sporadically but can occur in clusters in athletic teams. It has been characterized as a worldwide epidemic.

An athlete who plays contact sports is at particular risk given his or her skin-to-skin exposure and likelihood of skin breakdown. Sports at particular risk include football, rugby, and wrestling. Other individuals at increased risk include household members of infected people, military personnel, prisoners, urban dwellers in crowded living conditions, and HIV-infected individuals. Transmission occurs through person-to-person contact either via an infected wound touching another athlete's open skin or via secretions from an individual who is a carrier contaminating an open wound. The CDC has reported that repetitive skin trauma with inconsistent coverage places the athlete at greatest risk. Other factors that have been associated with the spread of CA-MRSA include contaminated items and surfaces, crowded living conditions, and poor hygiene. Nasal cultures do not predict risk of infection. There have been several case reports of outbreaks in athletic teams, with some patients requiring admission for intravenous (IV) administration of antibiotics. Studies have shown that infection tends to occur on exposed extremities with previous skin trauma. Skin injury has been reported to effect a threefold increase in the likelihood of staph infection in players. Other considerations include athletes with conditions that break down the skin's integrity, such as atopic dermatitis/eczema.

Clinical Presentation

Patients often present with the chief complaint of a spider or insect bite. On physical exam, they exhibit a variety of skin manifestations. They may have a focal area of redness, warmth, and swelling, with underlying fluctuance that is tender to palpation consistent with an abscess. There may be isolated skin redness, warmth, swelling, and pain in the case of skin infection or cellulitis. An abscess can also have an overlying cellulitis. Multiple cutaneous lesions do occur. These lesions are typically tender, indurated nodules with a history of rapid growth. Nodules can rupture spontaneously, contaminating the surrounding skin with infected pus. CA-MRSA can be severe or appear similar to a simple staph infection. Folliculitis secondary to CA-MRSA can occur in the chest, flank, and scrotum. There may be associated systemic symptoms such as fever and malaise. Regional swollen lymph nodes can also be present.

Treatment

Treatment involves systemic antibiotics and incision and drainage of the abscess. CA-MRSA is typically susceptible to sulfamethoxazole-trimethoprim (Bactrim) and clindamycin. Typically, these agents are used alone. CA-MRSA has variable sensitivity to fluoroquinolone antibiotics, such as ciprofloxacin, with rapid resistance. There is a geographic evolution of antibiotic resistance. It is advised to culture wounds in order to identify the organism and determine its susceptibility. A phenomenon called *inducible resistance* has been developing in various cities, where a pathogen reported to be resistant to erythromycin and sensitive to clindamycin develops resistance to clindamycin during the course of treatment. In this case, it is advisable to use Bactrim. The duration of treatment should be a minimum of 7 days, with many infections requiring up to 14 days of antibiotics for resolution. A topical antimicrobial ointment such as 2% mupirocin can be applied to the cutaneous lesions as an adjunct to oral therapy. Severely ill CA-MRSA patients require hospitalization and IV medication with antibiotics such as vancomycin or linezolid.

Prevention/Return to Sports

Mupirocin, a nasal ointment antibiotic, has been implicated in eradicating carriers of HA-MRSA. However, nasal cultures do not correlate with risk of infection. If used for treatment, it would likely be most effective if administered to all players. Further studies are needed to validate this. Athletes involved in repetitive skin-to-skin contact should protect the exposed extremities. Areas of skin trauma and/or infection should be clean and covered with a clean, dry dressing. The CDC recommends frequent hand washing and showering, and avoiding sharing of personal items, such as towels, razors, and uniforms, that may have made contact with an infected wound. Sheets should be cleaned and dried completely in a dryer. Equipment and surfaces should be cleaned and sanitized.

Fungal

Fungal infections are transmitted by person-to-person contact, by animal-to-human contact, or directly from the soil. Athletes most at risk include wrestlers, rugby players, and football players, because of close contact among players and skin trauma. Fungi invade the top layer of the skin, causing a scaly lesion. The term *tinea* refers to a fungal infection. Tinea capitis is infection of the scalp. Tinea corporis occurs on the body and is also known as ringworm. Tinea cruris involves the groin region and is known as jock itch. Infections of the feet, that is, athlete's foot, are called *tinea pedis*. Fungal infection can involve the toenails. *Tinea gladiatorum* refers to fungal infection of the skin or scalp. It is spread among athletes through skin-to-skin contact and in warm, moist environments, which encourage the development of infection. Fungus can also be present on equipment. Approximately 10% to 20% of the world population is infected by a fungus. The most common location is the foot. Athletes who swim and are exposed to pools or run marathons are at highest risk.

Clinical Presentation

The clinical presentation of tinea varies based on its location on the body. Tinea corporis lesions are typically well-demarcated, red, scaly plaques with a central cleaning associated with flaking and itchiness. Areas of exposure at highest risk are the head, neck, and upper extremities. Scalp infections are manifested by a patch of hair loss overlying a gray, scaly plaque. Tinea cruris has large, red, well-demarcated scaling plaques on the inner thighs, groin, and pubic region. Tinea pedis can present in a variety of ways, including red, weeping, macerated skin with a fissure in the web space between the toes.

Diagnosis

The sports medicine provider can typically make the diagnosis of tinea infection based on the appearance and location of the skin lesions. Direct microscopy can confirm the diagnosis by revealing the characteristic hyphae appearance of a fungus, using a potassium hydroxide solution applied to a skin scraping. Fungal culture can also be used.

Treatment

Topical and oral medications can be used to treat tinea. Topical medications have few adverse effects and come in inexpensive forms but may take several weeks to take effect. Oral or systemic medications have a quicker onset of action but can have significant side effects and a higher cost profile. Tinea capitis does require an oral medication. Patients with uncomplicated tinea corporis or cruris can be treated with topical therapy. If topical treatment fails, then oral medication is instituted. Mild tinea pedis can be treated with a topical regime, with oral treatment being reserved for the more severe or chronic cases. Infections with an inflammatory response may respond to topical steroids.

Return to Sports

The National Collegiate Athletic Association (NCAA) and National Federation of State High School Associations (NFHS) have return-to-play guidelines for fungal and viral lesions in an athlete. The NCAA guidelines disqualify an athlete from competition until 72 hours of treatment with a topical fungicide has been completed or, in the case of tinea capitis, a minimum of 2 weeks of treatment with oral therapy. Lesions need to be covered with a gas-permeable membrane, that is, Tegaderm. The NFHS disqualifies athletes until 7 days of oral or topical treatment has been completed, with a minimum of 2 weeks of treatment for tinea capitis. There are no return-to-play guidelines for tinea pedis.

Viral

Viral infections in athletes are common due to the close skin-to-skin contact and environmental exposures. Interestingly, the abrasive shirts used in wrestling have been linked to development of viral skin infections. The more common viral infections include herpes, molluscum contagiosum, and warts.

Herpes Simplex

The *herpes simplex virus* (HSV) can cause infection around the mouth ("fever blisters") and on the genitalia. HSV Type 1 is associated with oral lesions, while HSV Type 2 causes urogenital lesions. Unfortunately, once an individual has been infected, he or she is susceptible to recurrent episodes due to reactivation of the latent virus in a nerve. Multiple factors have been associated with reactivation, including sun, stress, caffeine, and physical stress. Herpes is widely prevalent in the wrestling world, with most of the case reports and studies originating from this sport. The term *herpes gladiatorum* refers to herpes skin lesions in the athlete but more specifically indicates infection in a wrestler. The term *scrumpox* refers to HSV infection in rugby players. As is the case with other skin infections, lesions typically present themselves on exposed areas of the body, such as the head, extremities, or trunk.

Clinical Presentation. Herpes infection may present with the typical viral symptoms of fever, headache, muscle aches, and fatigue. The lesions are manifested by a group of painful vesicles on a red base that may proceed to ulceration. These vesicles can appear on the lips, hands (called *herpetic whitlow*), and body, and, rarely, on the eye. Ocular involvement is an indication for immediate evaluation by an ophthalmologist. Healing occurs over a 2- to 3-week period with progression of the lesions to scabs. Reactivated herpes presents with typical vesicular/ulcerative lesions without the associated systemic symptoms.

Diagnosis. Herpes is evident by its characteristic appearance. However, the Tzank test may be used to evaluate the fluid from a vesicle. A viral culture takes 4 to 5 days and is not normally indicated.

Treatment. Antiviral oral and topical medications are available for treatment. These include acyclovir, valacyclovir, and famciclovir. Studies have shown that acyclovir and valacyclovir are equivalent drugs in terms of length of treatment and time to lesion healing. Acyclovir has variable dose ranges from five times a day to twice a day, and valacyclovir is typically taken twice a day. In athletes with a known history of herpes, suppressive therapy has been advocated to prevent the lesions from recurring. Acyclovir 400 milligrams (mg) twice a day, valacyclovir 500 to 1,000 mg once daily, or famcyclovir 250 mg twice a day have all been recommended.

Return to Sports. The NCAA and NFHS each have recommendations regarding return to play for athletes infected by HSV. These are further delineated by primary or initial infection and reactivated or recurrent herpes. The NCAA proposes that patients with primary herpes gladiatorum return after being free of symptoms for 72 hours, having no new lesions for at least 72 hours, and having completed at least 120 hours of antiviral treatment. The NFHS recommends at least 120 hours of oral antiviral treatment and no new lesions while on medication. The NCAA recommends no moist lesions and at least 120 hours of oral antiviral treatment for reactivated herpes. The NFHS requires at least 120 hours of oral antiviral treatment and no new lesions.

Warts (*Verruca Vulgaris*)

Warts are noncancerous skin lesions caused by different types of human papillomavirus (HPV). Transmission is via skin-to-skin contact.

Clinical Presentation and Diagnosis. Warts typically appear on an athlete's hands, fingers, or feet. They are flesh-colored, roughly contoured plaques of variable size. Lesions on the soles of the feet are referred to as *plantar warts* and appear similar to calluses. Differentiation between the two involves paring down the lesion to reveal multiple "seeds" in the case of *plantar warts*. These seeds are the clotted vessels supplying the wart. Plantar warts can be very painful, making it difficult for the athlete to bear weight on the lesion. Rarely does a wart need to be excised and sent for confirmation of HPV. Warts can progress in size and appearance. Some disappear spontaneously, while some increase in size.

Treatment. There are many treatment approaches to warts. These include watchful waiting, over-the-counter remedies, cryotherapy, and surgical removal. Several attempts at treatment are typically necessary.

One of the more common treatments is cryotherapy, where treatment with liquid nitrogen induces inflammation, blister formation, and eventual sloughing off of the skin. Topical treatment with salicylic acid or trichloroacetic acid requires soaking before application and paring down the lesion after application to allow the treatment access to the active virus. Duct tape has been advocated as an excellent home remedy. Cantharidin is an extract from the blister beetle that induces a blister when applied, allowing the dead skin to be removed. Difficult warts may be treated with immunotherapy or laser surgery. There are no data supporting one treatment over the other.

Return to Sports. The NCAA return-to-play guideline recommends adequately covering the lesions. This has been loosely described and may be difficult depending on the location of the lesion. The NFHS does not have a guideline.

Molluscum Contagiosum

Molluscum contagiosum is a member of the poxvirus family. It is spread among athletes via skin-to-skin contact as well as contaminated objects such as shared clothing or towels. It typically infects young children aged 1 to 10 years but can also be spread via sexual contact in the younger adult population. It infects only humans and is easily transmitted among individuals.

Clinical Presentation. The lesions appear on the face, neck, trunk, arms, hands, and/or legs or, in the case of sexual transmission, on the genitals, lower abdomen, and/or inner thighs. They are round, raised, flesh-colored papules or nodules with a small indentation or "umbilication" at their center. Most patients are typically asymptomatic. The lesions can become red or inflamed, and if picked off, the virus will easily spread to the surrounding skin.

Diagnosis. Diagnosis is clinically made by the characteristic appearance of the lesions. Occasionally, skin scrapings are examined under the microscope for validation.

Treatment. In individuals with an intact immune system, the lesions will self-resolve in approximately 6 to 12 months. Treatment is recommended given the infection's ease of spread. There are multiple treatment options available, including scraping or curettage, freezing or cryotherapy, and laser surgery. Topical agents include 0.7% cantharidin, the blister-causing substance from the blister beetle, and silver nitrate. Immune modulating therapy has also been proposed. Associated dermatitis around the lesion can be treated with over-the-counter 1% hydrocortisone cream application, but the cream should not be placed on the lesion itself.

Return to Sports. The NCAA recommends curetting or removing the lesions and covering localized or solitary lesions with a gas-permeable membrane before the athlete can return to play. The NFHS recommends keeping a wrestler out of competition for 24 hours following interventions such as curettage.

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See also Friction Injuries to the Skin; Fungal Skin Infections and Parasitic Infestations; Pressure Injuries to the Skin; Skin Conditions in Wrestlers; Skin Disorders Affecting Sports Participation; Skin Infections, Bacterial; Skin Infections, Viral

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UpToDate.com: http://uptodate.com

Ingrown Toenail

Ingrown toenails are a common cause of toe pain. Usually occurring on the lateral (outer) side of the large toe, they are caused by abnormal growth of the nail plate into the surrounding tissue. The affected tissue responds to the invading nail plate as if it were a foreign body and becomes painful, inflamed, and occasionally infected. Common causes of ingrown toenails in athletes are poorly fitting shoes, hyperhidrosis (excessive sweating), and improper nail trimming. This problem is rarely seen in preteens, and its incidence increases with age. Minor ingrown nails are often treated at home without requiring medical attention. Severe cases may require a surgical procedure to remove the offending portion of the nail plate.

Anatomy

Several structures comprise the nail unit. The nail plate itself is made from dead keratin (cellular protein), which is hard and translucent. The nail plate lies directly on top of and is attached to a structure called the *matrix,* which overlies the nail bed. The nail plate grows out from the matrix at the base of the nail near a white crest called the *lunula*. The lunula is the only visible portion of the matrix. The nail plate extends out from the matrix across the nail bed until the two begin to separate where the nail covers a short piece of waterproof tissue called the *hyponychium,* near the tip of the toe. The portion of the nail that extends beyond the hyponychium and is fully independent of the matrix is called the *distal groove*. The *nail fold* is the skin and tissue surrounding the base and sides of the nail plate.

Causes

Any factors that press the nail plate against the skin of the nail fold can predispose individuals to ingrown toenails. Although any toe can be afflicted, the most common site of an ingrown nail is the lateral side of the great toe. Tight footwear, especially with a toe box that does not accommodate widening of the foot while bearing weight, is a common cause. Nail shape and length are also important factors causing a predisposition for ingrown nails. Nail plates should be trimmed so that the corners are squared and extend beyond the hyponychium, so as not to allow lateral growth into the nail fold. *Onychomycosis* (a fungal nail infection; see the entry Toenail Fungus) can cause nail plate thickening, which if left unattended can curve the nail, causing the nail plate to grow into the nail fold or crowd the toe, putting pressure on the nail fold. Hyperhidrosis is another contributing factor for ingrown nails because of the softening effect on the nail fold, making it susceptible to the pressures and lateral forces placed on it by the nail plate during exercise. *Neoplasms* (cancer) or previous trauma can also deform the nail shape, leading to ingrown nails. Other factors, which are less common in athletes, are obesity, gait abnormality, and skeletal deformities such as those seen in arthritis.

Symptoms

The progression of ingrown toenails is described in three stages. The first is the mildest, consisting of localized inflammation, edema (swelling), erythema (redness), and slight pain when pressure is applied to the lateral nail fold. The symptoms in Stage 2 are similar to those of Stage 1 but are more severe, including drainage and increased amount of pain because of infection. In addition to the symptoms of Stage 2, in Stage 3 the nail fold forms thickened granulation (scarlike) tissue overlying the lateral nail plate.

Treatment

The treatment for Stage 1 ingrown toenails is fairly conservative. It involves lifting the edge of the offending nail plate out from under the nail fold. Gauze or cotton is then placed under the edge of the sharp nail plate to prevent further irritation. Warm water soaks several times daily while irritation is present help soften the nail fold prior to cotton application. Stages 2 and 3 ingrown toenails generally require surgical intervention. This procedure can be performed in the primary care setting for most patients.

Typically, the affected toe is numbed by injection with a local anesthetic. Then a portion of the nail plate parallel to the nail fold is separated from the nail bed and removed. Any excess granulation tissue formed at the nail fold can also be removed at the time of surgery. If the entire nail plate is deformed or thickened due to onychomycosis, the entire nail plate is separated from the nail bed and excised (removed). The nail fold anatomy is abnormal as a result of the ingrown nail. If left to grow back, the nail has a high probability of becoming ingrown. To prevent recurrence, the exposed matrix of the excised portion of nail plate is destroyed using phenol, sodium hydroxide, laser, or electric cautery (knife). The athlete can generally return to activities the next day, keeping the surgical site clean and covered. The area heals and then fills in with granulation tissue over several weeks, forming a new nail fold. Caution should be used in patients with diabetes, peripheral artery disease, or other medical conditions that inhibit healing.

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See also Black Nail; Hammertoe; Hand and Finger Injuries; Hand and Finger Injuries, Surgery for; Toenail Fungus

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Insect Bites and Stings

Insect bites occur commonly in athletes, particularly those who train and compete in outdoor venues. Most bites result in mild reactions and often do not need treatment. Certain types of bites may go on to create a more widespread reaction, such as a rash or infection or, in severe cases, anaphylaxis. Anaphylaxis is a severe allergic reaction that causes difficulty breathing, wheezing, and low blood pressure and has the potential to lead to death if not treated quickly.

Not all insects produce venom. Hymenoptera are the only class of insects that produce venom, and only the female of the species makes the venom. Included in this class of insects are bees, wasps, hornets, and fire ants.

Blood-feeding arthropods, such as mosquitoes, can be challenging for athletes as well; many athletic contests occur outdoors and near the end of the day, when these insects are active.

Prevention of Insect Bites

Perhaps the most effective way to treat insect bites is by preventing them from occurring. Wearing protective clothing, using protective insect-repellent sprays, and avoiding known habitats when possible are effective means to reduce the occurrence of insect bites. Insect repellents containing DEET (*N,N*-diethyl-meta-toluamide) have been shown to be the most effective at providing broad-spectrum, long-lasting coverage against bites.

Mosquito

Mosquitoes are the most prevalent of the blood-feeding arthropods and worldwide can transmit more diseases to humans than any other arthropod. The name translates as “little fly,” derived from 16th-century Spanish or Portuguese. They are vectors for diseases causing encephalitis (brain inflammation) and arthritis (joint inflammation) and various febrile illnesses, including malaria and dengue fever. The female mosquitoes are responsible for bites as they need to collect blood for egg production. Male mosquitoes do not bite humans but rather feed from plants.

Mosquitoes are inherently persistent. They can bite any unprotected skin and even through thin layers of clothing. They find their prey by scent and the carbon dioxide in the exhaled breath. They tend to feed in the early morning or dusk hours of the day. They can feed many times in one breeding cycle, which means that one insect can bite multiple hosts.

Tick

Ticks are the most common vectors of disease-carrying arthropods in the United States. Ticks are most often either directly contacted in the outdoors—particularly in woody areas—or brought into the home by household pets. Ticks embed the front portion of their body (the feeding organ) into the victim's skin and remain there while feeding on the source's blood. If the tick has fed from an animal with a transmittable disease, it may carry the disease and yet itself remain unaffected by it. It is possible that the disease can be passed during the feeding phase to its human host. Some of the diseases associated with tick bites in the United States are Lyme disease, ehrlichiosis, Rocky Mountain spotted fever, and tularemia.

Removal of a tick requires great care so as not to leave a portion of the tick's body in the host. The tick embeds its feeding organ (hypostome) into the host, and this organ is equipped with reverse barbs that make removal challenging. To remove a tick, it is recommended that the tick be grasped firmly with pointed forceps as close to the skin as possible, taking care not to crush the insect. It should be pulled in a linear fashion out of the skin. It is *not* recommended that ticks be removed with bare or gloved hands. Methods such as using petroleum jelly, a lit match, or isopropyl alcohol on the tick are not recommended; they are more likely to cause expulsion of the salivary contents, leading to higher rates of disease transmission.

Hymenoptera (Bees, Wasps, Ants)

The class of hymenoptera has the ability to sting with the use of venom. Generally, these wounds inflict pain and invoke a rash that appears as a wheal (raised area of skin) and flare (intense redness). Most bee or wasp stings result in this local reaction only. In some people, however, the venom can cause severe anaphylaxis, which requires rapid treatment to reverse or halt progression to a life-threatening state. The first sting in one's life from a bee or wasp is unlikely to produce anaphylaxis but can sensitize an individual to the venom so that a subsequent sting can result in a more serious reaction.

Prevention of bee stings includes avoiding use of perfumes or aromatic lotions to decrease attraction of the insects. Awareness of bee habitats is important to avoid disruption of a hive, which can arouse numerous bees willing to sting to protect their home. Hives can be found around human dwellings (most often wasp hives) or in wooded areas in burrows located on the ground.

Treatment of a bee sting involves ice or cold packs applied on the sting site after attempting to remove the stinger. The edge of a credit card swiped gently over the sting often works well to remove the stinger. If the patient complains of any trouble breathing or chest discomfort or has a change in alertness, anaphylaxis may be setting in, and rapid transport to an emergency room is recommended. Anaphylactic reactions can occur up to 12 hours after the sting.

Fire Ants

Fire ants are more vicious than expected for their size. They tend to attack in large numbers and produce intense pain at the site of the bites. The ants are only about 1/16 to 1/4 inches (in.; 1 in. = 2.54 centimeters) long and live in colonies that can be identified by their characteristic mound of soft earth on top. Contact with the ants generally results in a rapid response, often before the victim is aware of the ants. Stepping on the mound may cause hundreds of ants to travel to the leg of the person and bite seemingly all at once. The bite tends to cause a burning sensation (thus "fire" ants) and eventually leads to small blisters filled with white pus. In allergic individuals, life-threatening anaphylaxis may develop. Treatment involves cool compresses and antihistamine medications to decrease the intense itching.

Caterpillars

Exposure to caterpillars can create skin irritation from contact with the short hairs (setae) of the caterpillar. Caterpillars are the larval stage for butterflies and moths. The hairs of the caterpillar may become airborne with some species and can become entangled with clothes hung to dry or directly with the skin. The irritated rash generally appears as small, red-colored bumps or pustules that may or may not be itchy. Following the life cycle of the caterpillar, the rash usually shows up in early spring.

Identification of the hairs of the caterpillar will confirm involvement of a caterpillar. Placing a piece of sticky, clear tape over the rash to pick up any small hairs that may be present and then putting that tape sticky side down on a glass slide allows for evaluation of the hairs with a microscope. Hairs that are present will appear as short, threadlike objects when looked at under a microscope. Treatment for the rash involves removing the hairs (gently with sticky tape as above), treatment with antihistamines or calamine lotion, and avoidance of further exposure when possible.

Spiders

Spiders are eight-legged creatures credited with many insect bites. Despite there being more than 34,000 species of spiders worldwide, most are not inclined to bite humans unless they find themselves in danger of being crushed themselves. A few spider bites are known to cause fairly typical clinical reactions and can at times be identified this way, but for most bites, the lesions they create are not specific, and it is impossible to tell what the consequences will be unless the actual biting spider can be collected.

The only two spiders of predictable clinical significance are the black widow and the brown recluse. This is because they tend to cause characteristic lesions at the site of injury.

Black widow envenomation occurs by the female of the species only. Muscle cramping often develops and most commonly may progress to severe pain in the abdomen and lower extremities. The lesion itself may be fairly innocuous—a mild redness or warmth about the area and possibly the presence of small fang marks. Black widows tend to be located in woodpiles or barns but also may migrate indoors to closets or cupboards in the winter. They tend to be prevalent in the southern part of the United States but have been seen in every state except Alaska. To help limit the spread of venom, ice should be applied to the bite area immediately. Antivenin is used for severe envenomations.

Brown recluse spider bites have the potential to produce a much more impressive local reaction. The mildest is redness and warmth at the site. Blistering can develop, however, as well as darkening of the skin and necrosis (dying of the skin). The lesion can take months to heal. These spiders are most commonly seen in warm climates and tend to be very reclusive (thus their name). Treatment for the lesions is usually ice, elevation, and gentle cleaning. Some bites may require antibiotics or anti-inflammatory medications to aid in healing. Tetanus toxoid immunization is important for moderate bites by any insect.

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See also Allergies; Anaphylaxis, Exercise-Induced; Emergency Medicine and Sports

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International Federation of Sports Medicine

The International Federation of Sports Medicine is made up of more than 120 national sports medicine associations (NSMAs) that span five continents. It is the oldest and largest confederation of national medical associations in the world.

History

This organization was founded on February 14, 1928, during the Second Olympic Winter Games in St. Moritz (Switzerland) as Association International Medico-Sportive (AIMS). Delegates from 11 countries elected Wilhelm Knoll

(Switzerland) as its first president. The organization's stated goals were as follows:

- To cooperate with and support the International Olympic Committee (IOC) and the international sports federations
- To provide the best medical care for athletes
- To provide support for the further development of NSMAs
- To organize the exchange of information and experience about the basic science and practical aspects of sports medicine

The first International AIMS Congress took place during the ninth Olympic Summer Games in Amsterdam (the Netherlands).

In Chamonix (France) at the third International AIMS Congress (1934), the name of the organization was changed to Fédération Internationale de Médecine Sportive (FIMS). FIMS received its present name (International Federation of Sports Medicine) at the 26th World Congress (1998) in Orlando, Florida.

Structure

FIMS is governed by a Council of Delegates, which is made up of one representative from each of the NSMAs. The council meets every 2 years and elects the executive committee (EC) for a term of 4 years. The EC meets at least twice annually. The EC consists of a president, four vice presidents, a secretary general, a treasurer, and eight members. The four vice presidents are nominated by each of the four continental federations: The Pan American Confederation of Sports Medicine (founded 1975), the African Union of Sports Medicine (founded 1982), the Asian Federation of Sports Medicine (founded 1990), and the European Federation of Sports Medicine Associations (founded 1997).

The "fifth continent," Oceania, nominates one member to the FIMS EC.

Four Standing Commissions—the Scientific, Education, Interfederal, and Liaison Commissions—support the FIMS EC. The chairs of these commissions, appointed by the EC, participate in the FIMS EC meetings.

Representatives of the International Olympic Committee (IOC), the International Council of Sport Science and Physical Education (ICSSPE), and the United Nations Educational, Scientific and Cultural Organization (UNESCO) also participate, as co-opted members, in the meetings of the EC.

Objectives

FIMS promotes the study and development of sports medicine throughout the world; research on the implications of physical training and sports participation; education by organizing or supporting national and international scientific meetings, courses, and congresses; medical care for the benefit of athletes; and physical training and sports participation for the health and fitness of all people. In addition, FIMS publishes scientific information on sports medicine and cooperates with national and international organizations in sports medicine and related fields.

John B. M. Wesseling

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Interval Training/Fartlek

Athletic events such as distance running predominantly use the body's aerobic energy system for production of adenosine triphosphate at a muscle-cellular level. While training for such events, athletes and their coaches look for methods to stress the aerobic system to stimulate the system to work more efficiently. This will often result in performance gains for the athlete as a consequence of the increase in mitochondrial density, better capillary network, and improved extraction of oxygen from the blood.

Stressing the aerobic system has risks in that exceeding the limits of aerobic power typically requires vigorous exercise, which necessitates relative rest for adequate recovery. The need for balancing a sufficient amount of stress to the aerobic system without excessive exercise loads (and the risk of prolonged recovery) has led to the introduction of interval training. There may also be physiological benefits in interval training for non-athletic populations (persons with a history of chronic obstructive pulmonary disease, asthma, or stroke) seeking to improve clinical parameters.

Interval Training

Interval training is defined as repeated short bouts of exercise at intensities that are higher than what can be sustained aerobically. Each short bout of exercise (work phase) is followed by a period of rest or recovery. The intensity of the work phase dictates the sustainability of that intensity. Hence, depending on the training intensity, a single effort may last from a few seconds to several minutes, with multiple efforts separated by up to a few minutes of rest or low-intensity exercise. Intense interval exercise is considered a time-efficient strategy to stimulate endurance muscle adaptations comparable with traditional training.

Distance runners often practice intervals on a running track, running hard at a certain pace for a specified distance (or time) and jogging, walking, or resting in between (for a set distance/time). An example could be 12 repetitions of 400 meters (m) with a 200-m jog between each. Distances can also vary; one example would be a "ladder" workout consisting of one 1,600-m, two 1,200-m, three 800-m, and four 400-m repetitions, each at an appropriate speed and recovery.

Interval training elicits rapid skeletal muscle remodeling due to the high level of muscle fiber recruitment, engaging Type II fibers in particular. Signaling pathways have been shown to play a role in promoting coactivators involved in mitochondrial generation.

A sufficient amount of interval training, performed for at least 6 weeks, increases peak oxygen uptake and the maximal activity of mitochondrial enzymes in skeletal muscle.

Fartlek

Originated in the 1930s by the Swedish coach Gösta Holmér (1891–1983), fartlek means "speed play" and has been adopted by many physiologists since. It describes a type of training that lies somewhere between interval training and distance training. It consists of distance running with a burst of harder running at more irregular points, lengths, and speeds than in interval training. Not only is it an efficient training method; Fartlek training has been suggested to help avoid injuries that often accompany continuous, repetitive activity and provides the opportunity to increase exercise intensity without exhausting the aerobic and anaerobic systems, thus extending the period before the onset of fatigue. Most Fartlek sessions last a minimum of 45 minutes, with intensity varying from walking to sprinting. Fartlek training is generally associated with running but can include almost any kind of exercise.

Sessions should be at an intensity that causes the athlete to work at 60% to 80% of his or her maximum heart rate.

Example of Fartlek Training

- Warm-up—easy running for 5 to 10 minutes
- Steady, hard speed for 1.5 to 2 kilometers (km), such as a long repetition
- Rapid walking for about 5 minutes—recovery
- Easy running interspersed with sprints of about 50 to 60 m, repeated until tired
- Easy running with "quick steps" (speeding up to avoid being overtaken)
- Full speed uphill for 175 to 200 m
- Immediately after, fast pace for 1 minute
- Repeats of this routine until the time prescribed on the schedule has elapsed

One of the main reasons for the success of Fartlek training is its adaptability. It can benefit participants in field games such as soccer, field hockey, lacrosse, and rugby as it develops aerobic and anaerobic capacities, both of which are stressed in these sports. Athletes can make the most of the flexibility of Fartlek training by mimicking the activities that would take place during their chosen sport or event.

Soccer

Endurance interval training using an intensity at 90% to 95% of maximal heart rate in 3- to 8-minute bouts has proved to be effective in the development of endurance and for performance improvements in soccer play. The training seems to mainly accomplish $\dot{V}O_2max$ (peak oxygen uptake) with intervals, enhancing lactate elimination; hence, aerobic endurance capacity and soccer performance both improve.

Chronic Obstructive Pulmonary Disease (COPD)

In athletes and healthy older adults, interval training has been shown to improve $\dot{V}O_2max$, endurance capacity, and lactate and ventilatory threshold. Peak work rates are higher after interval versus continuous training. Interval training may be more physiologically beneficial for patients with chronic obstructive pulmonary disease (COPD). In such patients, exercise work rates that are above a certain critical power cannot be sustained due to rapidly developing hyperinflation and dyspnea. Interval training appears to reduce this ventilatory response, delaying hyperinflation and dyspnea and allowing a greater opportunity for exercise progression. Interval training also specifically targets skeletal muscle metabolism, the dysfunction of which also contributes to exercise limitation in COPD. Finally, interval training may better mimic the activities of daily living and, thus, has a greater potential to improve quality of life by directly enhancing performance in key tasks such as climbing stairs.

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See also Aerobic Endurance

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Intervertebral Disk Disease

Neck and back pain are very common reasons for seeking medical attention. About 20% of the population will experience low back pain lasting for a month over a 1-year time period. For the neck, this is about 10%. In athletics, this is variable and sport specific. After a week of touring, 40% to 50% of cyclists will experience neck pain, while 30% will experience back pain. Although there are multiple causes of neck and back pain, the intervertebral disk is one of the most common sources of neck and back pain. In the triathlete, the disk has been a causatory factor in about 25% of these pain syndromes. As such, it is important for the athlete to understand the biomechanics of the specific sport and how his or her particular body type and underlying problems might be affected.

Anatomy

The spinal column spans from the skull to the pelvis. There are 7 cervical vertebrae, 12 thoracic vertebrae, and 5 lumbar vertebrae. These vertebrae articulate with the adjacent levels via the intervertebral disk in the front and the facet joints in the back.

The lumbar vertebrae end on the sacrum, which is a fused, V-shaped vertebra and articulates with the pelvis to transfer forces from the trunk to the legs (Figure 1).

The intervertebral disks become progressively larger from the cervical spine down through the lumbar spine. These disks have three basic components: the *annular ligaments* on the outside, the colloidal gel (*nucleus pulposus*) on the inside, and the *end plates* of the vertebrae above and below. The annulus is composed of well-organized concentric ligamentous sheaths (10–20 layers). The nucleus pulposus is a hydrous gel with a few cells and some inflammatory enzymes. It provides shock absorption to the spine, as well as motion. The end plates are at the top and bottom of the vertebrae, where the disk attaches. Since there is no blood supply, the end plate provides nutrition to the disk from the hydrostatic pressure during motion. In the child and adolescent athlete, these endplates are composed of soft growth cartilage and are susceptible to injury.

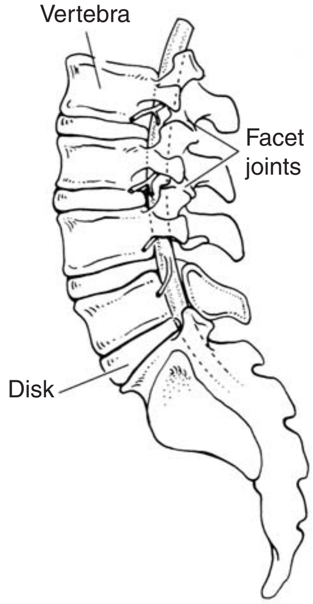

Figure 1 Portion of the Lumbar Spine Showing the Relative Positions of Intervertebral Disks and Vertebrae

The disks are crescent shaped, with the posterior curved away from the posterior spinal column. The one exception is the lowest disk at the lumbosacral juncture (L5-S1), which is round.

Pathologic Disk Problems

A number of changes occur to the disk over a lifetime. Some are part of a normal process that does not involve injury or pain. As we age, many disks will lose the hydration of the nucleus pulposus, losing some height and appearing darker on magnetic resonance imaging (MRI) studies. These are often normal, benign findings.

Conversely, a number of disk changes may occur that are sometimes associated with pain. However, it is crucial to understand that all the following changes may occur with no associated pain. Making the association between a pathologic change seen on an MRI scan and pain is often difficult. The different pathologies of the disk include degenerative disk disease, annular tears, herniated disks, and disk disease of adolescence. Degenerative disk disease occurs with disk dehydration and loss of the annular ligament strength, leading to instability with excessive motion and stress to the vertebrae above and below. This manifests with irregularities of the end plate and swelling (edema) in the adjacent bone. MRI may show edema in the bone, a dark disk, and tears of the annular ligaments. These changes can be correlated with pain.

An annular tear represents a tear of just the annular ligaments. Here, the nucleus is intact, but there is a simple tear in the outer annulus, where there are pain fibers. These tears may be from an acute traumatic episode or a chronic overuse syndrome. MRI will often show a white line in the normally dark annulus. (The nucleus is white, and the annulus is dark on some MRI scans.) This is called a *high-intensity zone* (HIZ) and has been somewhat correlated with pain.

A herniated disk is a more advanced phase of the annular tear. A herniated disk can be a bulge, a protrusion, an extrusion, or a sequestration. A *bulge* occurs when the ligaments are intact, but there is diffuse (180°) disk bulging. This common finding does not usually generate pain. A *protrusion* occurs with partial focal tear of the ligaments and is a broad-based disk protrusion of the nuclear gel. An *extrusion* represents a complete focal annular ligament tear and is a more narrow-based gel extrusion, but it remains in contact with the central gel. A *sequestration* occurs when this extrusion separates and migrates away from the disk (Figure 2).

The nerves of the body emerge from the spinal cord. The beginning portion of the nerve, as it emerges from the spinal cord and passes through the intervertebral foramen, is called the *nerve root.* A herniated disk may occur near or away from the nerve roots. When it affects the nerve roots, pain and weakness of the muscle groups may occur in the distribution of the nerve supply. In the neck,

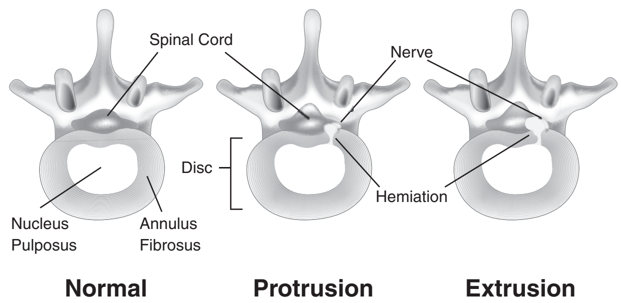

Figure 2 Stages of Intervertebral Disk Herniation

this will often produce shoulder, scapular, or arm symptoms. In the thoracic spine, the symptoms will often distribute to the anterior chest or abdomen. In the lumbar spine, the distribution involves the buttocks, thighs, lower leg, and/or feet. These radiating symptoms are called *radicular symptoms* and may be secondary to nerve compression from the herniation or nerve irritation from leakage of the inflammatory enzymes. Alternately, when the disk does not affect the nerve roots, there may be central pain in the neck, upper back, or lower back, depending on the level involved. This is called an *axial pain syndrome*.

Disk injuries in the cervical spine mostly occur at the lowest cervical levels: C5-C6 and C6-C7. Analogously, the lower lumbar spine is also affected: L5-S1 and L4-L5. Thoracic disk injuries are very uncommon but usually affect the lower thoracic spine.

Disks in children and adolescents are unique, with the end plate being a soft growth cartilage. Excessive pressure on the disk will cause a herniation through the weakest area of the growth cartilage, which will protrude down into the vertebral body, causing large end plate irregularities. In the thoracic spine, this will cause anterior wedging of the vertebrae, resulting in an excessively rounded back, called *Scheuermann kyphosis* (see the entry Scheuermann Kyphosis). When this occurs in the upper lumbar spine, it causes a more flat back and is called *atypical Scheuermann kyphosis*.

Risk Factors

Risk factors for disk disease include smoking, obesity, genetic factors, lack of core conditioning, hard labor, and sedentary lifestyles. From an athletic standpoint, there are a number of sports with strong associations with disk problems due to the biomechanics of the sport. These include wrestling, power lifting, crew, and cycling. When the spine is loaded in the flexed position, excessive pressure is imparted to the disk. For instance, power lifting and the catch phase of the crew stroke may place excessive pressure on the disk. Cycling is complex, depending on the type and duration; often the neck is placed in an extended position, which may apply shear force to the disk. Cycling in certain postures may also adversely flex the lumbar spine, causing low back pain from disk degeneration.

The young athlete with excessive flexion and extension, such as a gymnast, is at a much higher risk of atypical Scheuermann disease.

Clinical Presentation and Evaluation

Athletes with degenerative disk disease will more often present with an axial, nonradiating pain syndrome. It is often better during activity and worse at rest. But as the condition advances, it will be constant and will usually be somewhat relieved when the patient is in a recumbent position.

Athletes with an annular tear may present with an acute onset of axial pain related to one motion, such as a wrestling takedown, but the condition may also have a gradual, insidious onset, such as in a cyclist. This pain manifests classically during flexed activities, particularly sitting. On examination, forward flexion often causes pain, but pain may also occur on extension.

The athlete with disk herniation will present in a similar manner to the athlete with an annular tear but may have radiation along the nerve root path. In many cases, the arm or leg pain will far surpass the neck or lower back component. Again, flexion activities commonly aggravate the symptoms.

The young athlete with atypical Scheuermann disease will present with midback pain that worsens with both flexion and extension. On examination, there will be midback tenderness, aggravated with any motion, and a flat back appearance on forward flexion.

It is essential to inquire about any worrisome problems in the athlete that may prompt an immediate evaluation. These would include loss of ability to hold the urine or stool, fever, chills, weight loss, weakness of an extremity, or constant night pain. In the absence of these, full imaging is warranted if the symptoms last longer than 6 weeks in the adult or 3 weeks in the young athlete. Magnetic resonance imaging (MRI) is usually the most appropriate imaging tool, but a computed tomography (CT) scan may be useful if MRI is not possible.

Treatment

Treatment should follow a specific sequence: acute, subacute, rehabilitation, and sport-specific phases. During the first few days, there is relative rest with the use of analgesics. Rest should not exceed more than a few days. As the initial inflammation subsides, the subacute phase of isometric strength is begun. Here, the core muscles or upper trunk muscles, if the neck is involved, are activated without motion. When this is tolerated, the rehabilitative phase follows, with dynamic, low-resistance exercises used with progression. Finally, as the athlete regains full strength, the sport-specific phase begins, with conditioning aimed at simulating sport-specific motions and regaining proper form. One caveat is that the cervical spine disk involvement typically requires more gradual progression initially, as motion is poorly tolerated.

Since the disk involves inflammatory components, an anti-inflammatory medication is very useful, along with analgesics. In refractory cases, epidural injections of corticosteroids are very useful in accelerating the recovery phase. The adolescent athlete will often benefit from bracing to allow better rehabilitation.

Finally, surgery is considered in three situations: (1) progressive muscle weakness, (2) loss of bowel or bladder control (emergent), and (3) refractory symptoms. The latter situation is somewhat subjective. In cases of severe pain, surgery may be considered as early as 6 to 8 weeks after onset. In moderate cases, it may be months before surgery is considered. If surgery is performed, the athlete with a simple disk excision may possibly be ready for sports participation in 6 to 8 weeks.

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See also Gymnastics, Injuries in; Neck and Upper Back Injuries; Scheuermann Kyphosis

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Intracerebral Hematoma

A hematoma is a collection of blood outside the blood vessels. The term *intracerebral hematoma* refers to a collection of blood within the substance of the brain. These hematomas occur as a result of damage to the blood vessels that supply the brain tissue. In the general population, intracerebral hematomas are most often the result of head trauma or high blood pressure. Blood vessel abnormalities such as aneurysms, or abnormal masses in the brain, can also lead to hemorrhage and subsequent hematoma formation. In the setting of athletics, an intracerebral hematoma is usually the result of head trauma. It is a relatively rare but very serious type of head injury in sports and can lead to significant disability or death. Knowing the warning signs that can help identify an intracerebral hematoma can help prevent a potentially serious outcome. Quick medical attention is essential in these cases.

Anatomy

The majority of the brain's blood supply comes from a circuit of blood vessels known as the *circle of Willis.* The circle of Willis sits on the bottom surface of the brain and receives its flow of blood from two pairs of arteries that travel up through the neck. The left and right *carotid* arteries travel up through the front half of the neck. The left and right *vertebral* arteries course behind them. Soon after these four arteries pass through the skull, they join together to form the circle of Willis. The circle of Willis then sends off branch arteries to all regions of the brain. Each of these arteries separate into smaller and smaller branches throughout the entire brain. Intracerebral hematomas can occur when any of the arteries that lie within the brain itself become compromised.

Mechanism of Injury

An intracerebral hematoma can occur in sports as a result of a direct impact to the head or whenever enough force is transmitted to the brain and its arteries via an acceleration-deceleration mechanism. An intracerebral hematoma forms when the force is sufficient to cause physical damage to the arteries, resulting in blood leaking or hemorrhaging out of the vessels into the brain tissue. If the hematoma is being formed from damage to an artery rather than a vein, the blood is under tremendous pressure. This can lead to a quick expansion of the hematoma, which can then increase the pressure inside the skull. Given that the skull is a rigid, fixed space, this increase in pressure can quickly lead to damage to the brain itself and even death.

Risk Factors

The baseline risk of developing an intracerebral hematoma from sports participation is primarily a function of the type of sport being played, the equipment being used, and the playing technique of the athlete. While high-velocity contact sports such as football, ice hockey, and lacrosse may carry the most inherent risk, the use of proper equipment, especially helmets that meet the requirements set forth by the National Operating Committee on Standards for Athletic Equipment (NOCSAE), can lower the risk significantly. It is important to recognize that intracranial hematomas can occur in any sport in which an athlete experiences a head trauma. Certain sports that involve high velocities, entail less intentional contact, and require little, if any, protective equipment, such as soccer and field hockey, may pose additional risk.

Any athlete who is on a blood-thinning medication has additional risk of developing a hematoma. It should be noted that athletes using warfarin, or a similar medicine, do so for the purpose of preventing clots from forming in their heart or blood vessels. Since they are unable to form clots, as they would when not on the medicine, any hemorrhage can take on life-threatening characteristics quickly. The use of these medicines should therefore be a very strong consideration for avoiding contact sports. Other medications that thin out the blood, but to a lesser degree, such as aspirin, are relative contraindications for contact sports participation.

Another risk factor for developing an intracerebral hematoma is the presence of an abnormality in blood vessel anatomy. Certain congenital vessel abnormalities, such as an arteriovenous malformation (AVM), present significant bleeding risks. AVMs are typically identified on a brain magnetic resonance imaging (MRI) scan. The presence of an AVM requires consultation with a neurologist and/or neurosurgeon prior to clearing any athlete for competition. Connective tissue disorders can also lead to a weakening of the blood vessel walls.

Signs and Symptoms

The first sign of any type of brain injury typically involves some change in consciousness. The change can be subtle, such as mild confusion, or more dramatic, such as a complete loss of consciousness. The athlete may also have many of the signs and symptoms typically seen in concussion, such as headache, nausea, dizziness, sensitivity to light, and lack of coordination. Please refer to the entry Concussion for a more complete discussion of this injury. Any athlete who experiences a hit significant enough to cause concussion-like symptoms should be observed closely for any signs of the condition worsening. If any athlete develops new symptoms several minutes after a witnessed impact or if there is any perceived clinical worsening, emergency medical services should be notified immediately.

Clinical Evaluation

As with any athletic head injury, care should be taken on the field to first assess the "ABCs" (airway-breathing-circulation). The next consideration should be for cervical spine trauma, with cervical immobilization performed when appropriate. The athlete's level of consciousness should be noted using the Glasgow coma scale. Any language, memory, or orientation abnormalities should also be noted. A careful physical examination should be performed to evaluate for skull fracture or any focal neurological abnormality, such as pupil asymmetry, visual field loss, facial asymmetry, focal weakness, or coordination difficulties. Any evidence of fracture or focal neurological abnormality warrants activation of emergency medical services. Once the on-field assessment is complete, it is appropriate to monitor the athlete with serial physical examinations in order to document any changes in signs or symptoms. If worsening is noted, the patient should be further evaluated in a hospital setting.

Diagnostic Tests

The presence of an intracerebral hematoma can usually be confirmed with a computed tomography (CT) scan of the head. An MRI scan of the brain can also be used. While the MRI scan may provide more information regarding damage to the brain itself, it is more expensive, requires more time, and is not available at every medical facility. The initial diagnosis, therefore, is typically made with a CT scan.

Management

Athletes who are suspected to have any type of intracranial bleeding should be transferred via emergency medical services to the nearest emergency facility as soon as possible. If the injury is confirmed, the patient should then be evaluated for possible surgical intervention. Surgical options include evacuation of the hematoma as well as repair of the vascular structures and the skull, if needed.

Prevention

As with other head injuries in athletics, proper technique, well-fitted and certified equipment, and adherence to the rules of play are paramount in preventing an intracranial hematoma. Identifying any of the specific risk factors described above can help prevent significant injuries, disability, or death.

Return to Sports

No athlete should return to participation in contact sports as long as he or she is still symptomatic from any head injury. In the case of an intracerebral hematoma, the specific location and cause of the bleed need to be considered, and return to contact sports participation should only take place after consultation with a physician.

Jeffrey S. Kutcher

See also Concussion; Epidural Hematoma; Head Injuries; Intracranial Hemorrhage; Neurologic Disorders Affecting Sports Participation; Subarachnoid Hemorrhage; Subdural Hematoma

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Intracranial Hemorrhage

An intracranial hemorrhage is a type of head injury that involves bleeding inside the skull. The term *intracranial* refers to the location of the bleeding being inside the cranium. *Hemorrhage* refers to blood leaving the blood vessels. When blood collects outside the blood vessels, *hematomas* are created. Intracranial hemorrhages occur when a blood vessel inside the skull is damaged, resulting in rupture or leaking. In the setting of athletic competition, this can occur when a significant mechanical force is applied to the head. The resulting hemorrhage can be extremely dangerous and should be considered a medical emergency. Early recognition of the warning signs and quick medical attention are critical.

Anatomy

The bones of the cranium fuse together during early childhood development, forming a hard protective covering around the brain. Together, the cranium and jaw, or mandible, constitute the skull. The delicate tissues of the brain are enclosed completely within the cranial compartment.

Intracranial hemorrhages can be further delineated by location into intra-axial or extra-axial. *Intra-axial hemorrhages* refer to bleeding inside the brain tissue itself. *Extra-axial hemorrhages,* conversely, refer to bleeding that occurs outside the brain tissue but inside the cranium. Extra-axial intracranial hemorrhages can be further classified by location based on the three protective tissue layers that encase the skull, the *meninges*. The innermost protective layer, the *pia mater,* is a delicate membrane lying on the surface of the brain. The second layer, the *arachnoid mater,* covers the brain and pia mater but does not follow the contour of the involutions of the brain. The outermost layer, the *dura mater,* provides a thicker and tougher layer of protection.

These three layers define three potential spaces for blood to collect. The *epidural space,* between the skull and the dura, the *subdural space,* between the dura and arachnoid layers, and the *subarachnoid space,* between the arachnoid and pia layers, each have their own potential sources of hemorrhage. The pia mater is too closely adhered to the brain and too fragile to act as a barrier for blood, and therefore, there is no potential space between the pia and the brain for a hematoma to form.

Mechanism of Injury

Intracranial hemorrhages can occur in sports as the result of a mechanical force applied to the head. This is usually from a direct blow to the head, but it can also occur with a sudden acceleration-deceleration mechanism without direct contact with the skull. The hemorrhage occurs when the mechanical force is significant enough to cause physical damage to the intracranial blood vessels.

Risk Factors

For any athlete, the baseline risk of developing an intracranial hemorrhage is primarily a function of the type of sport being played, the equipment being used, and the playing technique. While high-velocity contact sports such as football, ice hockey, and lacrosse may carry the most inherent risk, the use of proper equipment, especially helmets that meet the requirements set forth by the National Operating Committee on Standards for Athletic Equipment (NOCSAE), can greatly lower the risk. However, intracranial hemorrhages can occur in any sport in which an athlete experiences a head trauma. Certain sports that involve high velocities, entail less purposeful contact, and require little, if any, protective equipment, such as soccer and field hockey, may also pose additional risk.

Any athlete who is on a blood-thinning medication, especially a medicine such as warfarin, carries additional risk of developing a hemorrhage. It should be noted that athletes using warfarin, or a similar medicine, do so for the purpose of preventing clots from forming in their heart or blood vessels. Since they are unable to form clots, as they would when not on the medicine, any hemorrhage can take on life-threatening characteristics quickly. The use of these medicines should therefore be a very strong consideration for avoiding any type of contact sport. Other medications that thin out the blood, but to a lesser degree, such as aspirin, are relative contraindications for contact sports participation.

Signs and Symptoms

The initial signs and symptoms of an intracranial hemorrhage depend specifically on the location of the bleeding. As discussed in the cross-referenced entries noted below, the first sign of any type of brain injury occurs shortly after the head impact and typically involves some change in consciousness. The change can be subtle, such as mild confusion, or more dramatic, such as a complete loss of consciousness. The athlete may also have many of the signs and symptoms typically seen in concussion, such as headache, nausea, dizziness, sensitivity to light, and lack of coordination. Please refer to the entry Concussion for a more complete discussion of this injury.

Any athlete who experiences a hit significant enough to cause concussion-like symptoms should be observed closely for any signs of worsening of the condition. The most common type of intracranial hemorrhage that would occur in this setting is an *epidural hematoma.* In the classic presentation, an epidural hematoma causes the athlete to experience what is known as a *lucid interval.* After an initial period of altered consciousness that can last several minutes, the athlete improves significantly, or even completely. During this time, the physical examination can be completely normal. At this stage, the epidural hematoma is still small enough to be asymptomatic. As it expands, however, the increasing pressure inside the skull puts the brain at risk, leading to a quick return of symptoms. Continued expansion of the hematoma can then lead to rapidly progressive symptoms, coma, and even death. The lucid interval typically lasts only a few minutes, whereas the subsequent deterioration can occur even faster.

Clinical Evaluation

As with any head injury, the first step is to assess the "ABCs" (airway-breathing-circulation). The next consideration should be for cervical spine trauma, with cervical immobilization performed when appropriate. The athlete's level of consciousness should be noted using the Glasgow coma scale. Any language, memory, or orientation abnormalities should also be noted. A careful physical examination should then be performed to evaluate for skull fracture or any focal neurologic abnormality, such as pupil asymmetry, visual field loss, facial asymmetry, focal weakness, or coordination difficulties. Any evidence of fracture or focal neurological abnormality warrants activation of emergency medical services. Once the on-field assessment is complete, it is appropriate to monitor the athlete with serial physical examinations in order to document any changes in signs or symptoms. If worsening is noted, the patient should be further evaluated in a hospital setting.

Diagnostic Tests

The presence of an intracranial hemorrhage can most easily be confirmed with a computed tomography (CT) scan of the head. While a magnetic resonance imaging (MRI) study of the brain may provide more information regarding damage to the brain itself, it is more expensive, requires more time, and is not available at every medical facility. The initial diagnosis, therefore, is typically made with a CT scan.

Management

Athletes who are suspected to have any type of intracranial hemorrhage should be transferred via emergency medical services to the nearest emergency facility as soon as possible. If the injury is confirmed, the patient should then be evaluated for possible surgical intervention. Surgical options include evacuation of the hematoma as well as repair of the vascular structures and skull as needed.

Prevention

As with other head injuries in athletics, proper technique, well-fitted and certified equipment, and adherence to the rules of play are paramount in preventing intracranial hemorrhages.

Return to Sports

No athlete should return to participation in contact sports as long as he or she is still symptomatic from any head injury. In the case of an intracranial hemorrhage, the specific location and cause of the bleed need to be strongly considered, and return to contact sports should only occur after consultation with a physician.

Jeffrey S. Kutcher

See also Concussion; Epidural Hematoma; Head Injuries; Neurologic Disorders Affecting Sports Participation; Subdural Hematoma; Subarachnoid Hemorrhage

Further Readings

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Irritant Contact Dermatitis

Irritant contact dermatitis (ICD) is a condition of the skin in which chemicals or mechanical or environmental forces irritate the superficial protective layers. This irritation leads to a localized inflammatory response typically resulting in redness and swelling. Dermatologic injuries are common in athletics, and given the diverse environmental conditions and chemical exposures encountered in sports, ICD is a commonly seen diagnosis. Recognizing ICD is important as there are strict policies for athletes with infectious skin conditions, and identifying noninfectious conditions such as ICD will help avoid unnecessary treatments and competition restrictions.

Causes

Many substances can cause ICD, the most common being chemical detergents, solvents, acids, dust, and excessive water. Disinfectants in swimming pools, fiberglass in hockey sticks, field markings in football and soccer, and chalk in weight lifting have all also been implicated in athletic cases of ICD. By far, the hands are the most commonly affected area of the body, and frequent exposure to soaps and cleaners accounts for more than 80% of occupational skin disorders.

Pathophysiology

ICD occurs when an irritating substance or repeated physical action damages the superficial protective skin barrier, the epidermis, and allows foreign material to come into contact with the layers below. This then causes a localized inflammatory reaction in the lower skin layers. Both chemical and physical agents can cause cellular damage. While some chemicals are directly caustic to cell membranes, repeated physical forces, such as friction, pressure, or occlusion, can all directly damage the epidermal cells. Environmental factors such as heat, low humidity, and ultraviolet light can also contribute to epidermal irritation. Heat typically leads to sweat production, which can enhance the permeability of chemical irritants. Low humidity environments can dry out the superficial skin layers enough to decrease the effectiveness of the skin barriers. Finally, ultraviolet light can penetrate through the epidermal layers and directly cause release of inflammatory mediators.

The amount of substance, length of exposure, and concentration of the chemical solution are all factors that can affect the severity of ICD. Larger volumes and longer exposure times enhance chemical permeability and increase the likelihood that cell damage will occur. Higher concentrations of chemicals are typically more irritating than more dilute solutions. Many studies have also documented that individuals with an atopic predisposition (i.e., eczema) are more susceptible to ICD as their skin can have an enhanced reaction to certain irritants and environmental conditions.

Both acute and chronic ICD exist. Acute ICD involves direct cytotoxic effects on the skin with rapid cell membrane damage. This typically produces a more vibrant inflammatory response. Chronic ICD occurs when the skin is repeatedly in contact with an irritating substance, and cellular damage occurs more slowly as cell membranes decompose over time. While an inflammatory response also occurs in this setting, it is typically less intense but can involve a more extensive area.

Clinical Evaluation

History

In acute ICD, there is usually, but not always, a history of exposure to an irritant. Symptoms such as burning, stinging, or itching can immediately follow an exposure or may present within a few minutes. Chronic ICD symptoms set in more slowly, and similar symptoms occur only after cumulative exposures. Repeated exposure is required to break down the epidermal cells, which, in some instances, can take up to a few weeks. Unlike allergic contact dermatitis (ACD), ICD does not require prior exposure and can occur after the initial contact with an irritant. If numerous athletes present with similar symptoms, ICD should be considered if an infectious etiology is ruled out as multiple teammates are rarely allergic to the same substance. Identifying whether uniforms or equipment are causing excessive friction over the skin, causing breakdown, is also important.

Physical Examination

Skin findings of acute ICD include redness, swelling, and even blistering if significantly irritating. The location of the skin findings is limited to the area of exposure. Acute ICD does not spread on its own, so the borders of the rash are sharply demarcated. In the chronic state, skin findings include redness, dryness, chapping, scaling, and fissuring. The decreased inflammatory response limits the amount of swelling. The borders are less distinct as repetitive exposures rarely occur in the exact same location. Spreading to other areas of the body does not happen, unlike in ACD, where the allergen can be transferred easily by the clothes or hands. Skin patch testing, which identifies allergies to certain substances, can be helpful to distinguish the two processes.

Treatment

The mainstay of treatment is to avoid contact with the offending irritant by wearing protective clothing or by not touching the substance. That may be difficult if a chemical irritant is involved, as many different chemicals can cause ICD. Determining what chemicals may be used in cleaning pools or wrestling mats may be necessary. Acute ICD may need to be treated in the same way as burns if the irritant is caustic enough. Keeping the area clean and protected from reinjury will allow the body to re-form a protective barrier. Also, modifying the sporting equipment to prevent excessive friction or to aid in sweat dissipation can quicken the healing process and decrease the reoccurrence of ICD. For treatment of chronic ICD, besides limiting exposure to the irritant, using moisturizers (e.g., petroleum jelly, thick lotions) to help restore the protective border of the skin can be helpful. Typical corticosteroid creams can help alleviate the itching and burning sensations.

Return to Sports

Unlike infectious dermatologic disorders, ICD is not a contraindication for participating in sporting competitions. Differentiating between the two is helpful to avoid removal from play. Using a protective barrier to cover the ICD-affected area can help the athlete avoid reexposure or further injury while participating in sports.

John Hatzenbuehler

See also Allergic Contact Dermatitis; Dermatology in Sports; Friction Injuries to the Skin; Jogger's Nipples

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J

Jersey Finger

The injury commonly known as *jersey finger* is an avulsion injury of the longer flexor tendon, the flexor digitorum profundus (FDP) tendon, that occurs after forceful extension during active flexion of the most distal part of the affected finger (aka the distal phalanx). The common name arises from the classic presentation caused by violent traction of a flexed distal phalanx as in catching onto the jersey of a running football player. In 75% of cases, the injury occurs in the FDP of the ring finger, followed closely by the middle digit. The injury most commonly occurs in athletes participating in rugby, football, and ice hockey, as well as those who have poor physical conditioning and a previous or untreated jersey finger.

Anatomy

The palmar side of the finger consists of both long and short flexor tendons. The shorter tendon works to bend the finger at the second crease (also known as the *proximal interphalangeal joint*, or PIP joint), while the longer one flexes the digit at the third crease (known as the *distal interphalangeal joint*, or DIP joint). The FDP originates from the proximal two thirds of the ulna and the tissue between the bones of the forearm, known as the *interosseous membrane*. The tendon then travels through the carpal tunnel (the divot at the proximal part of the palmar), extends just below the flexor digitorum superficialis (FDS) tendon (or the short flexor tendon) on the palmar surface, and then becomes more superficial as it inserts into the base of the distal phalanx. Neurologically, the ulnar and median nerves innervate the tendon at the little/ring and index/middle fingers, respectively. Segmental branches of the digital arteries provide its nutritional and vascular perfusion. An intact pulley system as well as adequate synovial fluid, which keeps the joint lubricated, define the range of motion of the FDP tendon, preventing it from gliding juxtaposed to the phalanges. Loss of either biomechanical utility leads to bowstring of the tendon, causing greater excursion of the FDP, increasing the amplitude of muscle contraction to obtain the same amount of phalanx flexion and, therefore, increasing the risk of injury.

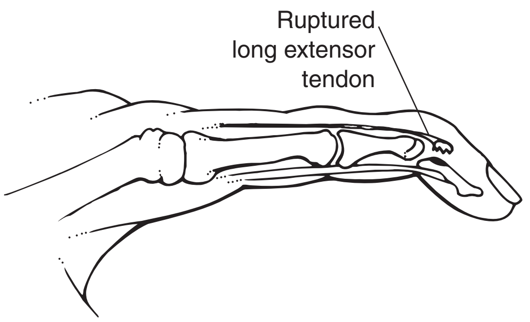

Figure 1 Jersey Finger

Mechanism of Injury

Defined as the disruption of the FDP on the palmar aspects of the distal phalangeal base, jersey finger leads to the loss of the bony or ligamentous attachment of the flexor mechanism into the distal phalanx, leading to loss of flexion at the DIP joint. The tendon can be torn directly from the distal phalanx, or it may avulse a bone fragment.

Three mechanisms of injury classically define the FDP avulsion. The type of mechanism plays a role in the determination of urgency in the treatment modality. In the first type, the tendon retracts into the palm, leading to substantial loss of blood supply. The second mechanism involves the FDP attachment retracting to the PIP joint with some blood supply preservation. In the third type of injury, the FDP avulsion (or chipped injury) can occur when a bony fragment avulses from the distal phalanx while preserving the blood supply.

Evaluation

Patients clinically present with localized tenderness and swelling with an inability to flex at the DIP joint. Some associated pain or fullness at the proximal course of the FDP tendon can occur due to retraction after rupture. When evaluating the natural resting position of the injured digit from a normal finger, the injured phalanx will appear in a more extended position, lying flat outside its normal cascade. Swelling, redness, and bruising can occur for up to 48 hours after the onset of injury.

To test the functionality of the FDP tendon, the examiner asks the patient to hold out the fingers in extension. Then the examiner stabilizes the PIP and metacarpophalangeal (MCP; at the first crease of the finger) joints, preventing them from moving when trying to test the DIP joint. Finally, the examiner asks the patient to flex the distal phalanx. Inability of the injured distal phalanx to fully flex signals a possible injury to the FDP tendon. The presence of a slight DIP flexion does not rule out an avulsion fracture. Some flexor force can be transferred to the distal phalanx without the tendon itself having a bony attachment. Concomitantly, compressing the forearm flexion muscles should draw the noninjured phalanx into flexion compared with the injured.

Initially, an X-ray of the affected finger should be obtained to rule out an avulsion fracture. Magnetic resonance imaging (MRI) can be used to accurately diagnose the disruption of annular pulley ligaments of the injured tendon. With the increasing use of ultrasounds, this modality has shown increasing promise as a tool for diagnostic purposes.

Treatment

Surgical intervention remains the primary treatment modality for all injuries involving the FDP tendon. Optimally, repair should occur within 24 hours of the injury. In the first type of injury, repair is warranted as soon as possible, while there can be some moderate delay of up to 2 weeks in the second type and up to 2 months in the third type.

Repair involves exposed knots and stitched or sutured ends to better promote adhesion formation, while core and running sutures placed around the tendon are used for tensile strength. Most individuals are successfully treated with this treatment modality, but in older patients and those with recurrent injuries, fusion of the DIP joint may be warranted for a better outcome.

After surgery, a dorsal splint (placed at the back of the hand) is used to keep the wrist and the joints in 30° and 70° of flexion, respectively, while placing the DIP and PIP joints in extension. A rubber band traction then maintains the digits in flexed position, providing tendon excursion to repair the injured FDP in order to minimize stress. The splint is kept on for 3 to 5 weeks, after which gentle hand exercises are started, with the protective splint removed only to perform the exercises. Removal of the splint occurs after the fifth week with advancement of light function of the hand and resisted exercises are started after 8 weeks.

Failure to treat the injury in time can lead to permanent deformity, joint stiffness or dysfunction, rerupture, and arthritis.

Return to Sports

After controlled motion in a customized splint 5 weeks postoperation to allow tendon healing and consequent physical therapy, considerations of return to play concern whether the patient's sport involves use of the affected part. Involvement in sports is often delayed for at least 3 months after surgery. If the patient requires use of the affected hand, then it is recommended that return to play is delayed 4 to 6 months after surgery while physical therapy is practiced.

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See also Finger Dislocation; Finger Fractures: Overview; Finger Sprain; Hand and Finger Injuries, Surgery for

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Jet Lag

International travel is inevitable for elite athletes and their coaches, although many other people desire to exercise during international visits. The general travel fatigue associated with any international flight is quickly overcome, whereas jet lag is more long-lasting and is associated with desynchronization of circadian rhythms after time zones are crossed.

Jet lag symptoms, and their associated impact on athletic performance, depend on the duration and direction of the flight, the flight schedule, the time of day, and individual differences. Knowledge of the human circadian system can be used to develop interventions that accelerate adjustment of circadian rhythms and recovery from jet lag. In particular, the timing of outdoor or bright light exposure, meals, and exercise may be manipulated. Melatonin may be helpful, although daytime ingestion of this substance is discouraged among athletes, since it can induce drowsiness and can impair some aspects of athletic performance. Support staff should develop appropriate strategies for individual athletes, who might be assessed for chronotype (morningness/eveningness) or individual circadian phase (by measuring the circadian rhythm of core body temperature or salivary melatonin concentration). Informed strategies based on individual behavior can then be made to minimize the transient effects of jet lag on well-being and performance.

Travel Fatigue Versus Jet Lag

Any long journey by road, rail, or air can cause discomfort and fatigue. Long periods may be spent in a cramped posture, and there may be other stresses associated with delays, unplanned stops, or detours. When traveling by plane, there are added problems caused by hypoxia in the aircraft cabin. Although the cabin is pressurized, there is still some hypoxia present, which may lead to dehydration, dry airways, and headaches. Nevertheless, these transient problems can be remedied on arrival by rehydration, a rest or some light exercise, and a shower or bath. This travel fatigue is experienced when flying directly northward or southward, for example, from mainland Europe to Southern Africa or from North to South America. If only two or fewer time zones are crossed, travel fatigue is probably the most important problem to overcome, and jet lag symptoms will be negligible.

A syndrome distinct from travel fatigue, jet lag is experienced when long-haul flights cross multiple (more than two) time zones. Symptoms are due to a mismatch between the "body clock time" and the new local time and include feeling tired during the day in the new time zone and yet experiencing disturbed sleep at night, feeling less able to concentrate or to motivate oneself, decreased mental and physical performance, increased incidence of headaches and irritability, loss of appetite, and general bowel irregularities. The body clock gradually adapts to the local time in the new environment, and when this process is complete, the symptoms of jet lag disappear.

The Chronobiology of Jet Lag

The body clock works on a molecular level and is located within the suprachiasmatic nuclei (SCN) of the hypothalamus. The retinohypothalamic tract and the intergeniculate leaflet provide input pathways from the retina (photic signals) and other regions of the brain (nonphotic), respectively, to the SCN. A multisynaptic pathway from the SCN also leads to the pineal gland, where melatonin is secreted at night and suppressed by light. These pathways exist to help synchronize the body clock to a 24-hour period. Natural light is the predominant synchronizer for the body clock, and the effects depend on the timing of exposure. Light in the morning can advance circadian rhythms, and light in the evening can delay circadian rhythms. Exogenous melatonin can also shift the biological clock, but in opposition to the effects of light; melatonin in the morning delays circadian rhythms, whereas ingestion in the late evening leads to a phase advance. Additionally, melatonin has an acute lowering effect on core body temperature and alertness. The timing of physical activity has also been found to affect circadian rhythms, especially in animals. In humans, the effects are smaller and seem to depend on whether salivary melatonin secretion or core body temperature is measured as the marker of the circadian phase.

Factors Affecting Jet Lag

The severity of jet lag depends on the number of time zones crossed and, to a lesser extent, on the direction of travel. Symptoms are generally worse after traveling eastward compared with westward travel. Morning-type "larks" could have a theoretical advantage in adjusting to eastward travel (since their circadian phase is already relatively early in the day). Evening-type "owls" might cope better with a westward flight (since they may be naturally phase delayed). Nevertheless, the majority of people are intermediate in chronotype.

There is little evidence that jet lag symptoms are different between males and females, but older people may suffer more, especially in terms of sleep-related symptoms. If one has a choice over different flight schedules and arrival times, a late-afternoon or early-afternoon arrival might be advised, since individuals can "use" the travel fatigue to promote a full sleep at night in the new time zone sooner after arrival. Cultural differences in the country of destination do not affect jet lag, but the climate encountered may exacerbate symptoms of travel fatigue. For example, dehydration following a long-haul flight due to the dry cabin air may be exacerbated after arrival in a very hot country, especially if the destination is at a high altitude, as for a training camp.

Dealing With Jet Lag

The ultimate "cure" for jet lag is to allow enough time between arrival and any obligations (e.g., sports competitions) for circadian rhythms to adjust completely to the new time zone. This period will vary in accordance with the number of time zone transitions experienced. As a general rule, 1 to 1.5 days per time zone crossed should be sufficient. If this period of time is not feasible, strategies for minimizing the effects of jet lag can be applied preflight, while on board the aircraft, and following arrival in the new destination.

Some preflight adjustment of the sleep-wake cycle can be attempted in accordance with the direction of flight. Adjustment of more than 2 hours in retiring to bed is discouraged, since this change is liable to cause rhythm disturbance and impair the quality of training undertaken before departure. As soon as the flight begins, it is advised that travelers should set their watches and schedule meals and sleep periods in accordance with the time at the destination. Although the meal content has been found to affect human circadian rhythms, there is little evidence that the content of meals can be manipulated (e.g., made higher in protein or carbohydrate content) to hasten adjustment to the new time. It is the timing of the meal in the new environment that is more likely to help readjustment of the body clock. Adequate fluid ingestion is recommended, and caffeine can help in combating sleepiness experienced during the day.

Although benzodiazepines and nonbenzodiazepine soporifics have been advocated for inducing sleep, and some benzodiazepines may act as chronobiotics (i.e., change the phase of the body clock), their benefits are inconclusive in athletes. In contrast to benzodiazepines, melatonin can promote sleep without having any marked effects on the sleep EEG (electroencephalogram). However, the purity of melatonin bought in health food outlets or on the Internet cannot be guaranteed. It is also unclear whether melatonin helps most by consolidating sleep in the new time zone or by phase-shifting one's circadian rhythms. To achieve the latter, melatonin would need to be ingested during the day following some flights, depending on the direction of travel and the number of time zones crossed. Such dosing could impair daytime functioning and training.

Most chronobiologists agree that the safest and probably most effective factor in determining the rate of adjustment to the new time zone is seeking exposure to natural daylight and avoiding bright light at the most appropriate times. The timing of such behavior is crucial and should be based on the known phase-response characteristics to light (see above). After flying westward, the recommended times for exposure to, and avoidance of, light to phase-delay circadian rhythms tend to coincide with the daylight and nighttime periods, respectively, in the new time zone, and this could be one reason why westward flights are generally less problematic than eastward journeys. After flying eastward, a phase advance of the body clock is required. Therefore, exposure to light is recommended soon after the minimum in body temperature is reached. Nevertheless, a morning arrival in a new time zone 6 to 9 hours to the east of the home country may coincide with the body clock time that precedes this trough. At this time, the wearing of very dark sunglasses may reduce light exposure. According to the phase-response characteristics for light, exposure in the new afternoon is beneficial.

It should be noted that on the day of arrival, markers of circadian rhythms (useful for the most appropriate timing of light, etc.) will be unusually phased relative to clock time and will change throughout the postflight days. After an eastward flight across six to nine time zones, the minima of temperature and performance rhythms will be in the late afternoon (about 05:00 hours by time in the departure zone). Adjusting the body clock by phase advance will cause this nadir to advance through the afternoon and morning. Ideally, an athlete's circadian phase would be measured prior to the flight and throughout the postflight days to optimize the timing of behavioral strategies.

Greg Atkinson

See also Sleep and Exercise; Sleep Loss, Effects on Athletic Performance; Travel Medicine and the International Athlete

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Jock Itch

Jock itch is the common name for tinea cruris, a fungal infection of the skin localized to the groin and medial thigh. It may extend to the genitals and back to the perianal region.

Pathophysiology

Tinea cruris, and similar fungal infections such as tinea pedis (athlete's foot), tinea corporis, and tinea capitis (ringworm of the body and scalp, respectively) are caused by *dermatophytes*. Dermatophytes can be found on humans, animals, and in soil. They are transmitted by direct contact. The most common cause of jock itch is the dermatophyte *Trichophyton rubrum*.

Clinical Evaluation

History and Physical Exam

As the name implies, jock itch causes a burning or itching sensation in the affected areas. The region is usually large, red, and has a border that is easy to see. The affected skin may be flaky. It usually advances down the thigh, with the leading edge remaining red and scaly. The skin that has been affected longer may turn brown.

There is usually a history of the athlete remaining in sweaty clothes after workouts. Specifically, tight underwear and jockstraps allow for a warm and sweaty environment. This helps the dermatophyte to grow and cause the infection.

Diagnosis

Jock itch is usually diagnosed on clinical grounds alone, based on the location, appearance, and history of the rash. However, if there is a question, the diagnosis can be confirmed by a KOH (potassium hydroxide) test. The affected skin is scraped, allowing debris to fall onto a glass slide. Potassium hydroxide is added to the slide, and under a microscope, the examiner can see the dermatophyte.

Treatment

Medication

Jock itch is almost always easily treated with topical antifungal lotions. These have minimal side effects. Terbinafine, clotriamazole, and ketoconazole have all been effective. The cream must be applied twice daily for up to 4 weeks to completely treat the infection and decrease recurrence.

Oral medications are saved for people who fail topical therapy or have very extensive disease. The common medications are griseofulvin, terbinafine, and fluconazole. These medications work well but often have significant side effects, such as sensitivity to sunlight, upset GI tract, rash, and headache.

Prevention

Educating athletes on proper hygiene is important. Athletes should shower with soap and water immediately following every workout. They should put on clean clothes after the shower and not the clothes they have just worked out in. They also need to be aware that skin-to-skin contact can transmit fungal infections. Athletes should not share equipment without thoroughly washing it first.

Kevin D. Walter

See also Athlete's Foot; Fungal Skin Infections and Parasitic Infestations; Skin Disorders Affecting Sports Participation

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Jogger's Nipples

Also called runner's nipples or friction nipples, *jogger's nipples* results in painful, irritated, and sometimes cracked or bleeding nipples. Although it is most common in runners, as the name implies, it can be found in any type of athlete, male or female, where there is repetitive friction on the chest wall by clothing or equipment.

Epidemiology and Risk Factors

Although the data on the prevalence of jogger's nipples in athletes are scanty, it is a common occurrence. It is more prevalent in overweight individuals or large-breasted women, particularly with inadequate breast support. As expected, it is also more common in long-distance athletes who have prolonged or repetitive friction exposure. Cold weather, which leads to erect nipples, as well as rainy or wet environments predispose to irritation as well. Coarse fabrics or loose-fitting clothes can cause or worsen the friction.

Clinical Presentation

Patients usually present with a complaint of acute or chronic pain in their nipples, which can range from mild irritation to overt bleeding and significant discomfort. It is most often the nipple itself that is the most affected, but the areola (the dark area around the nipple) may be affected as well. Examination reveals a red, irritated nipple that may have cracks, scabs, or overt bleeding.

Prevention and Treatment

Prevention focuses on avoiding friction. Most commonly, this is achieved by bandage strips, commercially available nipple bandages (e.g., Nip Guards), or taping of the nipple. Petroleum jelly or a water-based lubricant applied before or during the event can also prevent friction. Clothing made from fine-woven and soft synthetic fabrics should be worn, and when running a race, new shirts or running bras should be avoided. For men, running without a shirt is the most effective prevention, if conditions and race regulations permit. For women, appropriate breast support is essential.

This is usually a self-resolving condition if further injury is prevented. Secondary infection can occur but is rare due to the excellent blood supply in the area. For mild irritation, a soothing aloe gel or simple skin lotion can bring comfort. For severe cracking and bleeding, an antibiotic ointment such as Neosporin can be used while the nipple heals.

Other Considerations

If nipples are not healing with appropriate treatment or if there is nipple discharge or bleeding without a history of trauma or friction injury, the patient should be seen by a physician or health provider to ensure that there is no other serious condition affecting the nipple or breast.

Peter E. Sedgwick

See also Friction Injuries to the Skin

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Joint Injection

Joint injection is a common medical procedure during which a medication is placed into a joint using a needle. It is only occasionally used in younger athletes, primarily because they tend to have normal joint function, but it is one of the cornerstones in the management of degenerative arthritis (osteoarthritis) in the older athlete. It can be helpful as well in athletes with inflammatory arthritis such as gout or rheumatoid arthritis. If present, joint fluid is often removed prior to completing the injection. Removing fluid from a joint is called *joint aspiration*. This can help relieve the pain produced by swelling and can aid in the diagnosis of the joint pathology. Joint injections are performed for diagnostic reasons as well. When a numbing medicine, such as lidocaine, is injected into a joint or around inflamed tissue, the athlete's response can help make the diagnosis. If the diagnosis is clear from the athlete's clinical presentation and examination, a joint or soft tissue structure may be injected with medication, typically an anti-inflammatory medication, to help relieve the athlete's symptoms of pain and swelling.

Indications

Diagnosis of Joint Pain and Swelling

There are many causes of joint pain and swelling. Infections (both bacterial and viral), degenerative changes, fractures, bleeding into the joint from trauma, inflammatory arthritis such as gout or rheumatoid arthritis, and mechanical irritation such as from a torn meniscus can all cause joint pain and swelling. Removing fluid from the joint can be very helpful in making the diagnosis. The physician can tell if blood, pus, or normal straw-colored fluid is present in the joint. Further analysis of the fluid with culture and microscopic examination of the types of cells in the fluid can help determine if bleeding, infection, or inflammatory arthritis is present. It is essential to determine the cause of joint pain and swelling in order to formulate an appropriate treatment plan.

Injection of a contrast material into a joint followed by computed tomography (CT) or magnetic resonance imaging (MRI) can help detect subtle injuries as well as more clearly identify the anatomic structures. This can help improve the sensitivity of these procedures as diagnostic tools.

Reduction of Inflammation and Pain

Once it is determined that joint injection is the appropriate course of action, medications can be injected into the joint to help reduce the inflammation and pain. Injected medications can be helpful when oral medications cannot be used or are not effective. It is a general rule in sports medicine that a joint should not be injected solely for the purpose of allowing an athlete to return to participation if there is a risk that further damage to the joint may occur.

Improvement of Joint Function

Sometimes, injections are given specifically to help with the joint function. Reduction of inflammation is certainly one way to achieve this, but there are also medications that when injected into a joint are believed to help with the healing of damaged articular cartilage. These can help improve joint function by decreasing pain.

Risks and Benefits

The decision to administer an injection should be made after careful consideration of the risks and benefits. The benefits are relief of pain and inflammation as well as improving joint function. Improvements may be temporary, and often several injections may be necessary to produce long-standing results. The risks include infection, bleeding, temporary worsening of the pain, skin discoloration, tissue degeneration, injury to the surrounding anatomic structures, and allergic reaction. The side effects of joint injection will depend, to some degree, on the type of medication injected. When using steroid preparations, it is generally recommended not to inject into weight-bearing joints (hip, knee, and ankle) more frequently than three times per year due to concerns about potentially accelerating joint degeneration.

There are several situations when a joint should not be injected. An anti-inflammatory medication should not be injected into an infected joint, and the needle should not be passed through an infected area of skin while performing the procedure.

Types of Medications Injected

Anti-Inflammatory Medications

The most common medication injected is a cortisone-related steroid. There are several different types, but they all produce a similar anti-inflammatory response. The most commonly injected medications are the long-acting steroids betamethasone and methylprednisolone acetate. It may take up to 2 weeks for maximum benefit, and the anti-inflammatory benefit typically lasts several months or longer.

Pain Medications

Both long-acting (marcaine) and short-acting (lidocaine) anesthetic medications can be used for joint injections. Long-acting medications will last 3 to 4 hours, and short-acting ones will last 1 to 2 hours. The anesthetic medication can be mixed in the same syringe with the anti-inflammatory medication and injected together. Pain relief is usually immediate. This rapid response can help confirm the diagnosis. It also helps confirm that the anti-inflammatory medication was placed in the correct anatomic location.

Viscosupplementation

Hyaluronan and hylan derivatives can be injected into a joint to help relieve osteoarthritis pain. These substances are components of articular cartilage and are thought to aid in the healing of the damaged articular surface. A series of three to five injections, given several weeks apart, is the usual course of treatment. Although not curative, some athletes can get temporary relief with the procedure. Occasionally, athletes experience an increase in joint inflammation from the medication.

Proinflammatory Agents

There is growing interest in injecting medications that produce inflammation in the joint. The theory is that this can promote healing and cause scar tissue to form. This can help reduce pain and improve function in specific clinical situations, such as when joint laxity is present. This procedure is commonly referred to as *prolotherapy*. The procedure remains controversial, and further research is needed to clarify its indications and effectiveness.

Common Injection Sites

Almost any joint can be injected. Some joints can be easily injected in the physician's office without the need for special equipment. These include the shoulder, knee, ankle, elbow, fingers, and toes. Other joints are more difficult to inject and require ultrasound or X-ray machines to visualize the anatomy. Joints most likely to require ultrasound or CT guidance include the hip, spine, and wrist.

Follow-Up

Athletes who receive joint injections are typically followed up by their physician to discuss the results of the joint fluid tests if fluid was removed and to assess the athlete's response. Exercise programs to help strengthen the muscles around the joint are often used along with injections to help improve joint function. In some clinical situations, repeat joint injections may be necessary.

Michael Henehan

See also Ankle Injuries; Elbow and Forearm Injuries; Knee Injuries; Shoulder Injuries

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JOINTS, MAGNETIC RESONANCE IMAGING OF

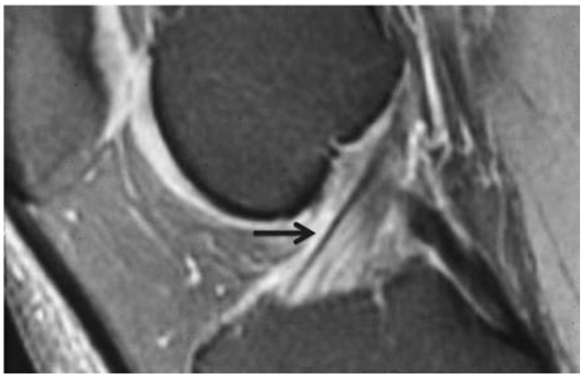
A radiologic evaluation of the joint typically begins with a series of radiographs to look for fractures, dislocation, or signs of degeneration. Other techniques such as computed tomography (CT), ultrasound, and magnetic resonance imaging (MRI) can provide more information regarding the internal structures that make up the joint, such as soft tissues, muscles, cartilage, ligaments, and tendons. Of these modalities, MRI is considered the gold standard and has most profoundly affected the practice of orthopedic surgeons.

In 2008 and 2009, arthroscopy of the knee and shoulder was the most frequently performed orthopedic procedure, with more than 1.5 million reported each year. Orthopedic surgeons use MRI to help select which patients are candidates for reparative arthroscopy in the knee and shoulder. Regarding diagnostic arthroscopy, many leading orthopedic surgeons prefer MRI due to its noninvasiveness and the accurate detailed information it provides. MRI is particularly helpful for sports medicine surgeons in evaluating the integrity of ligaments, tendons, menisci, and cartilage in the knee. Regarding the shoulder, MRI provides excellent diagnostic information regarding the rotator cuff and labrum, as well as identifying abnormalities that may mimic rotator cuff or labral pathology clinically.

Knee Imaging

Anterior Cruciate Ligament

The reported accuracy of MRI of the knee for anterior cruciate ligament (ACL) tears is nearly 100%, making it the examination of choice for evaluating the ACL. MRI can also delineate additional information on associated injuries such as medial collateral ligament, lateral collateral ligament, and meniscal injury. Given the global overview MRI provides of the knee, it is the exam of choice for evaluating suspected internal derangement.



Normal anterior cruciate ligament (ACL). Anterior is to the left. Sagittal fat-saturated image of the knee.

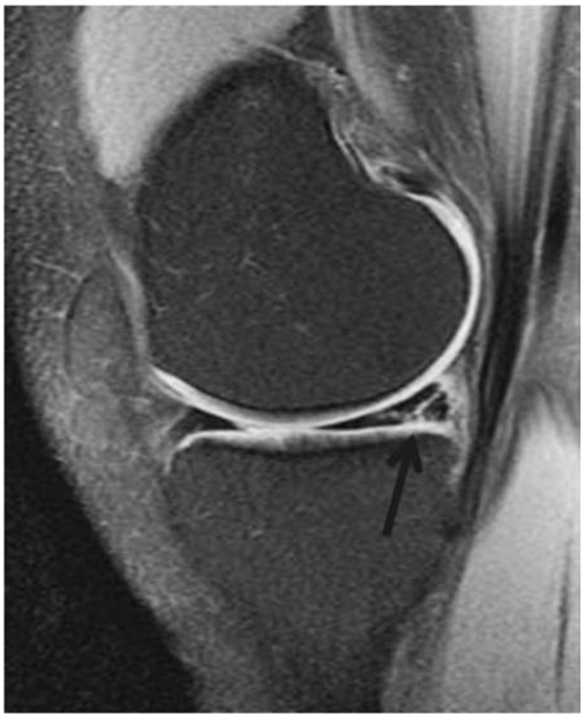
Source: Clyde Helms, M.D.

Complete anterior cruciate ligament (ACL) tear. Anterior is to the left. The normally low signal fibers are disrupted. Sagittal fat-saturated image of the knee.

Source: Clyde Helms, M.D.

Torn medial collateral ligament (MCL). Medial to the left. Fat-saturated coronal image of the knee demonstrates discontinuity and a wavy appearance of the MCL with adjacent edema.

Source: Clyde Helms, M.D.



Complex tear of the posterior horn of the medial meniscus. Anterior is to the left. The normally low signal triangular meniscus demonstrates two linear oblique tears extending to the articular surfaces. Sagittal fat-saturated image of the knee.

Source: Clyde Helms, M.D.

Menisci

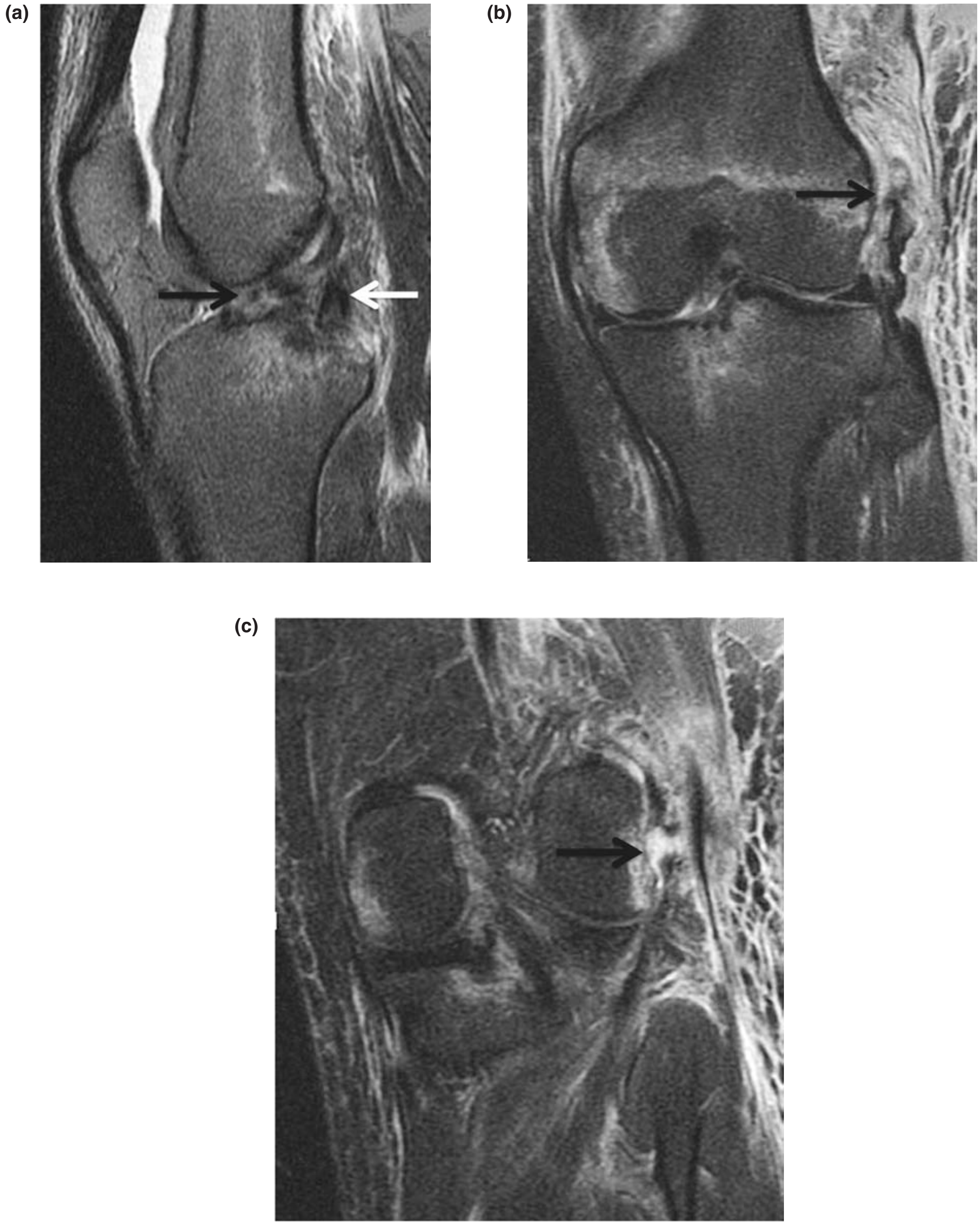
The reported accuracy of MRI of the knee for meniscal tears is 90% to 95%. This high accuracy has resulted in MRI being preferred to diagnostic arthroscopy by most leading orthopedic surgeons. One of the most important benefits of MRI for the menisci is helping the surgeon determine whether the symptoms are attributable to the meniscus (see image above, right).

Posterolateral Corner Injury

In addition to the ability of MRI to aid the surgeon with meniscal pathology, it can show the findings of a potentially career-ending knee injury for the elite athlete, the posterolateral corner injury. This can be debilitating even for the non-athlete if it is not surgically repaired. The posterolateral corner is composed of the lateral collateral ligament complex, the arcuate ligament, the popliteus tendon, and multiple smaller ligaments such as the popliteofibular ligament. If two or more of these structures, along with the anterior or posterior cruciate ligament, are torn, the injury is deemed a posterolateral corner injury. Many surgeons feel that prompt surgical repair (<1 week delay) affords the best outcome in these athletes. MRI is crucial in helping establish this diagnosis as many of the components of the posterolateral corner cannot be seen arthroscopically (see next page).

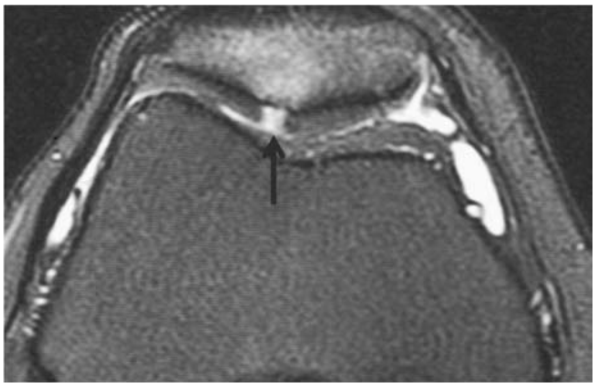
Hyaline Cartilage

Another area in which MRI plays a vital role in sports medicine is the imaging of hyaline articular cartilage in the knee. Newer surgical techniques are evolving that rely heavily on MRI for help in the identification and classification of cartilage abnormalities. Imaging techniques are rapidly evolving and improving to aid the surgeon in diagnosing pathologic conditions of cartilage (see left image, page 740).



Posterolateral corner injury. (a) Sagittal fat-saturated image of the knee with anterior to the left demonstrates complete tear of the anterior cruciate ligament ACL (black arrow) and complete tear of the posterior cruciate ligament PCL (white arrow); (b) coronal fat-saturated image of the knee with medial to the left demonstrates complete tear of the fibular collateral ligament; and (c) coronal fat-saturated image of the knee with medial to the left demonstrates complete tear of the origin of the popliteus tendon.

Source: Clyde Helms, M.D.



Cartilage defect. Axial fat-saturated image of the knee with medial to the right demonstrates a full-thickness cartilage defect at the patellar apex.

Source: Clyde Helms, M.D.

Normal rotator cuff. Coronal fat-saturated image of the shoulder demonstrates a normal broad footprint of the rotator cuff on the greater tuberosity.

Source: Clyde Helms, M.D.

Shoulder Imaging

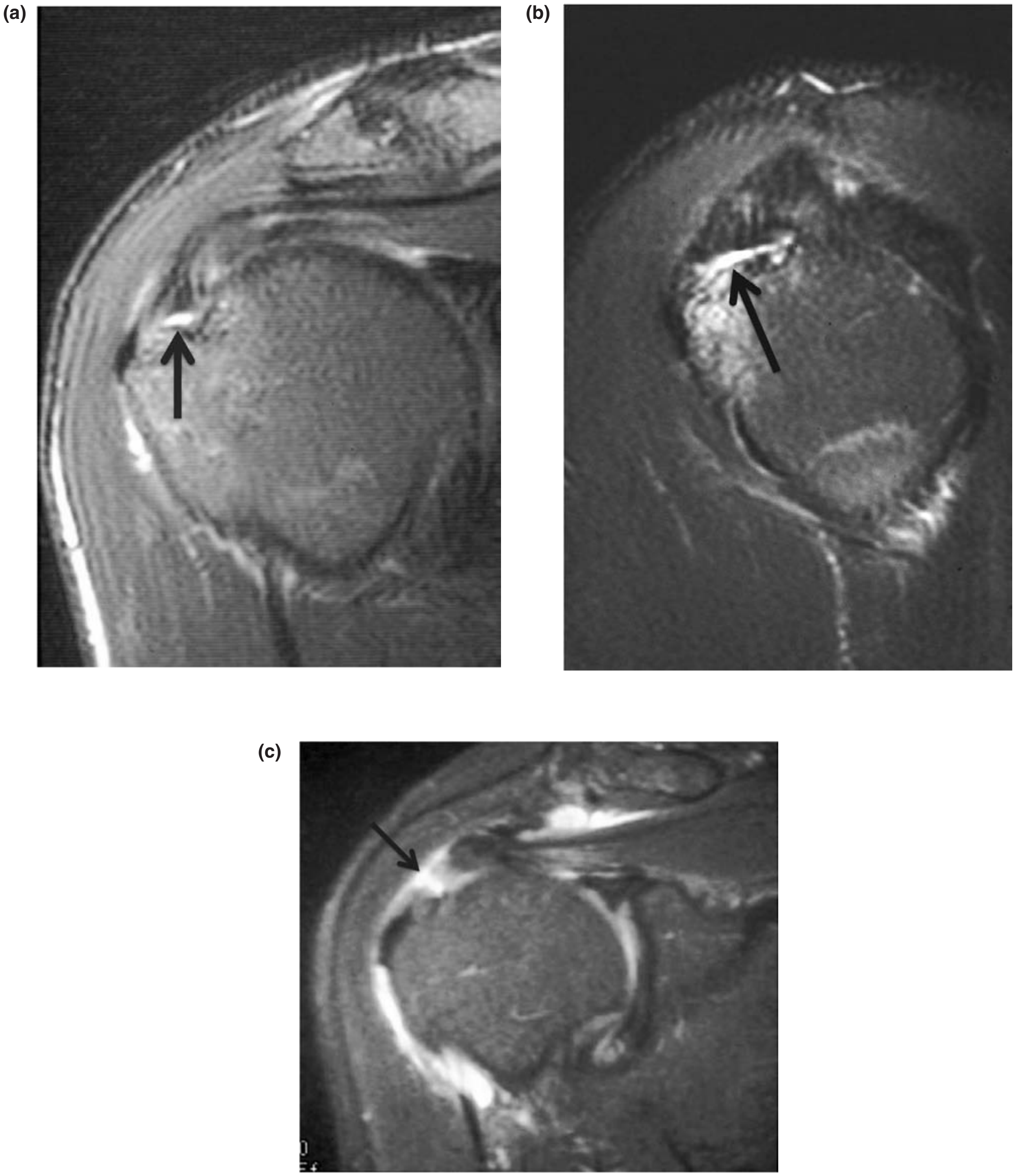
Rotator Cuff

The tendons of the rotator cuff are normally low in signal on all pulse sequences and are best seen on the coronal oblique images, in the plane of the supraspinatus tendon. The tendon inserts onto the greater tuberosity of the humerus with a low-signal, broad footprint. Cuff tears are classified according to the depth of the tear and described as partial or complete discontinuity of the normally low-signal tendon, with the gap filled with fluid signal on T2-weighted images. The reported sensitivity for partial-thickness tears is variable but approaches 90% with the use of magnetic resonance arthrography (MRA), which involves instillation of diluted gadolinium into the joint prior to MRI. The sensitivity for full-thickness tears is approximately 90% and nearing 100% with MRA (see above image, right; next page).

Glenoid Labrum

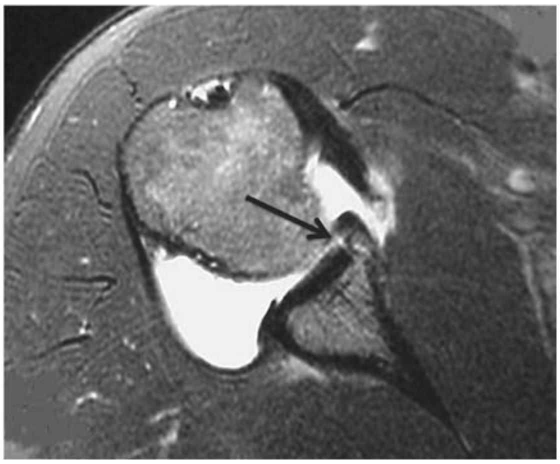
The normal MR appearance of the labrum is a low-signal structure, on all pulse sequences, and triangular in shape. Labral tears or detachments can be described according to location. The MR appearance of labral injuries depends somewhat on the severity and duration of the injury. Tears are diagnosed when there is a linear high signal or contrast extending across as least 50% of the substance of the labrum. Detachment of the labrum is described when there is a high signal extending between the labrum and the adjacent glenoid cartilage/cortex or if the labrum is completely displaced from the adjacent glenoid, and it may involve stripping of the adjacent glenoid periosteum. Sensitivity is greatly improved with the use of MRA, with reported sensitivities for detecting superior labral tears ranging from 82% to 100% and specificities between 71% and 98%.

Tears involving more than one quadrant are uncommon, and much less common are tears involving at least three labral quadrants, the so-called *triple labral lesions* or 180° tears. These tears have been described both following acute traumatic dislocations of the shoulder as well as in heavily muscled young males who engage in regular weight lifting. Specifically in these patients, the degree or extent of the tear is underestimated on the MRI scan and is often found to be more extensive on arthroscopy. However, the involvement of the posterior labrum in heavily muscled young males should prompt a more thorough search for additional labral pathology (see images p. 742).



Rotator cuff tear. (a) Coronal fat-saturated image of the shoulder demonstrates a partial articular surface tear at the supraspinatus insertion; (b) sagittal fat-saturated image of the shoulder (anterior to the left) demonstrates a partial articular surface tear at the supraspinatus insertion; and (c) coronal fat-saturated image of the shoulder demonstrates a full-thickness tear of the supraspinatus tendon.

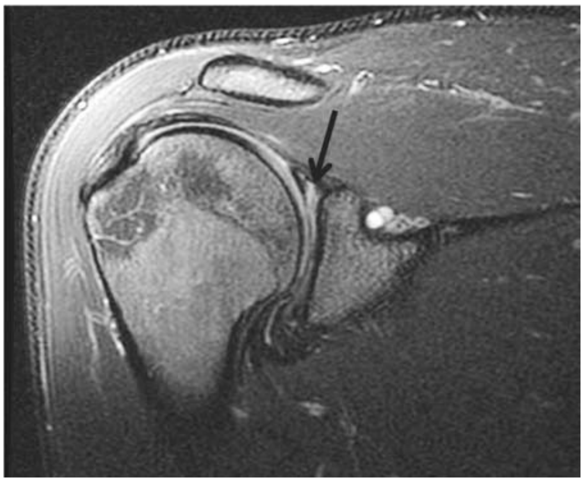
Source: Clyde Helms, M.D.



Anterior labral detachment. Axial fat-saturated image of the shoulder demonstrates an anterior labral detachment from the glenoid.

Source: Clyde Helms, M.D.

(a)



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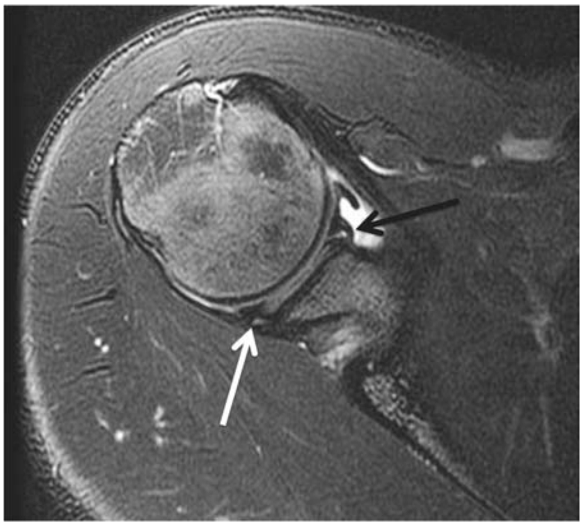


A 180° labral tear. (a) Coronal fat-saturated image of the shoulder demonstrates an anterior-superior labral tear and (b) axial fat-saturated image of the shoulder demonstrates an anterior labral tear (black arrow) and posterior labral tear (white arrow).

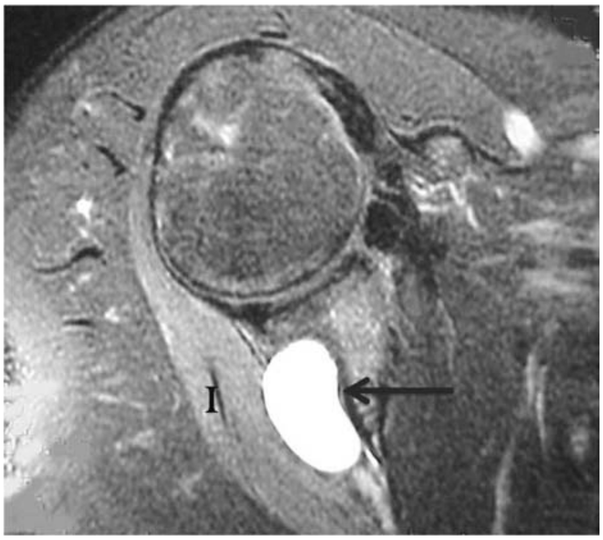
Source: Clyde Helms, M.D.

Paralabral Cysts

Paralabral cysts are thought to form from extrusion of joint fluid through a labral tear with the formation of a pseudocyst, which is a well-circumscribed unilocular or multilocular high-signal structure on T2-weighted sequences. Paralabral cysts are highly specific for adjacent labral tears, so that even when a labral tear is not identified, the presence of a cyst should prompt the assumption of adjacent labral injury. If the cyst extends into the spinoglenoid notch, there can be suprascapular nerve compression and subsequent trophy or neurogenic edema involving the infraspinatus muscle. The cyst cannot be seen in arthroscopy or open surgery. Therefore, MR imaging is critical in establishing the diagnosis and guiding the surgeon to the source of the pain (see image, next page, left).

Internal Impingement

Internal impingement can be used to illustrate the imaging characteristics of various soft tissue injuries of the shoulder, unique to the throwing athlete. It is a type of impingement that occurs with extreme abduction and external rotation of the humeral head during the cocking phase of the throwing motion. The exact etiology is debated but is generally thought to be secondary to contracture of the posterior band of the inferior glenohumeral ligament, resulting in shifting of the normal glenohumeral contact point more posterior and superior while the humerus is in the cocking phase. A combination of excessive



Spinoglenoid notch cyst. Axial fat-saturated image of the shoulder demonstrates a spinoglenid notch cyst (black arrow) with neurogenic edema in the infraspinatus muscle (I).

Source: Clyde Helms, M.D.

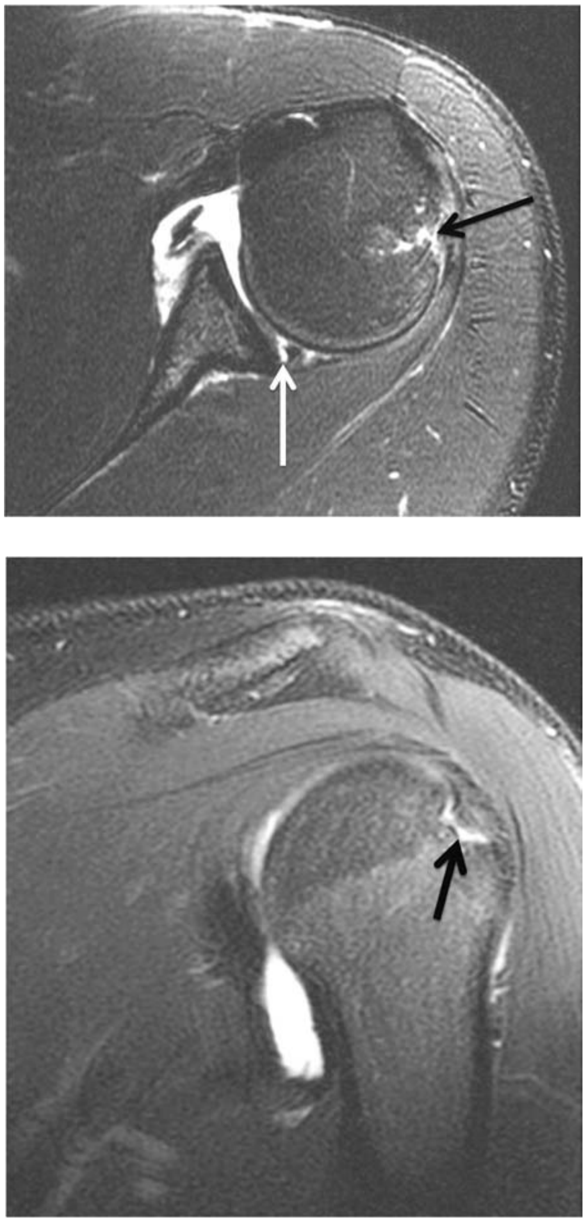
impaction of the posterior humeral greater tuberosity on the posterior superior glenoid as well as excessive torsional forces on the superior labrum and rotator cuff can lead to tearing of these structures. The combination of posterior superior labral abnormality, infraspinatus abnormality, and bony cystic changes in the posterior humeral head should suggest the diagnosis of internal impingement (see images, right).

Quadrilateral Space Syndrome

Quadrilateral space syndrome is a diagnosis that may be difficult to make on the basis of clinical grounds alone and may be confused with a rotator cuff tear or impingement, leading to unnecessary surgery. Quadrilateral space syndrome is a clinical syndrome with manifestations including poorly localized shoulder pain and paresthesias in the affected extremity in a nondermatomal distribution resulting from compression of the axillary nerve in the quadrilateral space, most often by posttraumatic fibrous bands. The quadrilateral space is an anatomic space in the

(a)

(b)



Internal impingement. (a) Axial fat-saturated image of the shoulder demonstrates cystic changes in the posterolateral humeral head (black arrow) and a posterior labral tear (white arrow) and (b) coronal fat-saturated image of the shoulder demonstrates a partial articular surface tear of the infraspinatus tendon at the insertion.

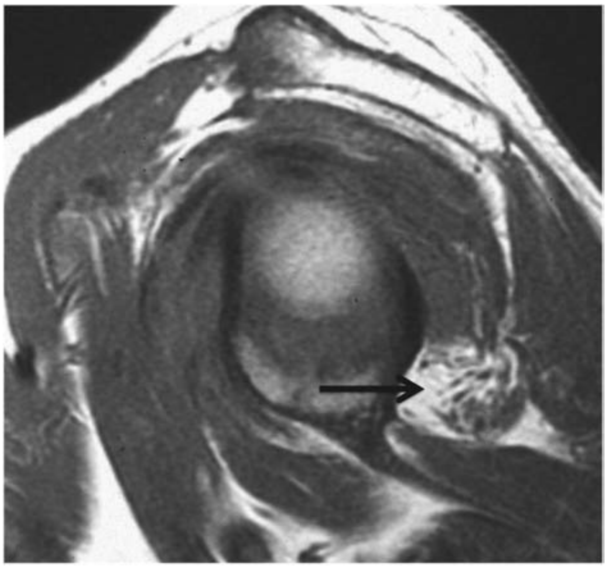
Source: Clyde Helms, M.D.

upper arm bounded by the long head of the triceps, the teres minor and teres major muscles, and the cortex of the humerus. On the MRI scan, this syndrome is manifested by focal atrophy involving the teres minor muscle without involvement of the deltoid muscle (see image below).

Parsonage-Turner Syndrome

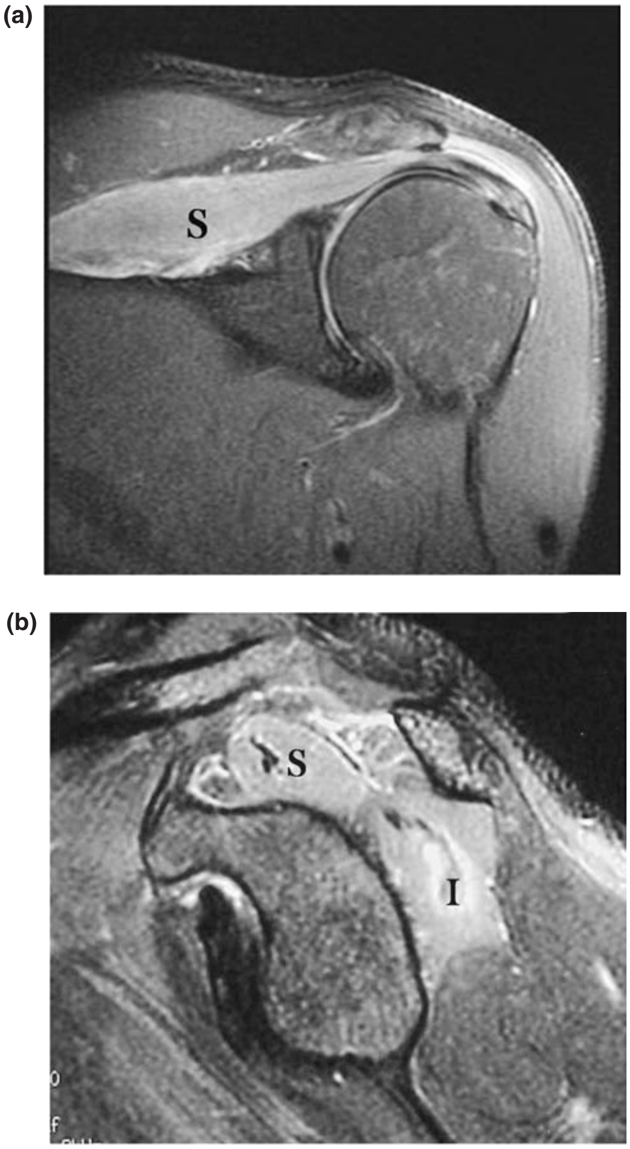
Parsonage-Turner syndrome (PTS), also called *acute brachial neuritis*, is characterized by the acute onset of severe neuritic pain, sometimes waking the patient from sleep, that is accompanied in a few days by profound weakness. The cause is unknown, but PTS is typically self-limited, with no known treatment other than palliative measures. PTS is often confused clinically with more well-known and common disorders such as cervical spondylosis, rotator cuff tear, and shoulder impingement syndrome. Multiple patients have undergone unnecessary surgery of the shoulder or cervical spine owing to failure to diagnose PTS.

The MRI finding most typical of PTS is that of diffuse high-signal intensity, depicted on T2-weighted images, involving one or more muscles innervated by the brachial plexus, with T1-weighted MR images possibly showing atrophy of the affected muscle(s). The pattern of muscular involvement should match the distribution(s) of one or more peripheral nerves originating from the brachial plexus, with the suprascapular nerve almost invariably involved (see images above).



Quadrilateral space syndrome. Sagittal image of the shoulder demonstrates fatty atrophy of the teres minor muscle.

Source: Clyde Helms, M.D.



Parsonage-Turner syndrome. (a) Coronal fat-saturated image of the shoulder demonstrates neurogenic edema in the supraspinatus muscle (S) and (b) sagittal fat-saturated image of the shoulder (anterior to the right) demonstrates neurogenic edema in the supraspinatus muscle (S) and infraspinatus muscle (I).

Source: Clyde Helms, M.D.

Hetal Patel, Thomas Scott Dziedzic, and Clyde Helms

See also Dual-Energy X-Ray Absorptiometry (DEXA); Orthopedist in Sports Medicine, Role of; Ultrasound

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Juvenile Osteochondritis Dissecans of the Knee

Osteochondritis dissecans (OCD) is a condition where a small section of bone just below the joint cartilage surface loses its blood supply and eventually dies. The cartilage overlying this area of dead bone can fragment and eventually break off into the joint. The condition occurs as a result of repetitive trauma (impact) to the bone, which eventually disrupts the blood supply to a portion of the bone. The overlying cartilage softens, progressively fragments, partially detaches, and eventually separates from the surrounding cartilage. The detached cartilage can become a loose body that can get caught in the joint with knee motion.

OCD can be divided into adult and juvenile forms. Juvenile OCD is defined as OCD occurring in an individual who still has growth remaining. The adult form may be the result of an unresolved juvenile OCD lesion. More than 50% of juvenile OCD lesions heal without surgery, whereas lesions that occur in adults rarely heal without surgical intervention.

Juvenile OCD is more commonly seen in males than in females and can be bilateral in up to 20% to 25% of patients.

Etiology

The etiology of osteochondritis dissecans is unknown. Suspected etiologies have included inflammation, family history (genetics), ossification abnormality, ischemia, and repetitive trauma.

Konig introduced the term *osteochondritis dissecans* in 1887. He believed that the condition began as an inflammatory condition affecting the subchondral bone and overlying cartilage, which then progressed to spontaneous avascular necrosis of the subchondral bone.

The relatively frequent occurrence of OCD in patients who are involved in sports supports repetitive microtrauma is a likely cause of OCD. It is thought that repetitive joint loading causes a local area of ischemia in the subchondral bone. When the frequency of the trauma exceeds the ability of subchondral bone to heal, the overlying cartilage softens, fragments, and may separate from the underlying bone. If the cartilage fragment detaches, a loose body forms within the joint.

Clinical Presentation

A child with OCD of the knee typically complains of a history of poorly localized anterior knee pain. A typical history is joint pain that worsens with activity and is relieved with rest. Instability is an uncommon complaint. A knee effusion or mechanical symptoms, such as catching or locking, is uncommon unless the cartilage overlying the OCD lesion has fragmented.

The physical examination for an OCD lesion of the knee should include a complete examination of the knee to rule out other causes of anterior knee pain, such as patellofemoral syndrome, a synovial plica, patella instability, Osgood-Schlatter disease, Sinding-Larsen-Johansson disease, or other cartilage or bone lesions.

The most common location of an OCD lesion is on the lateral aspect of the medial femoral condyle. Wilson described a test where symptoms were reproduced by internally rotating the tibia so that the tibial spine pressed against the OCD lesion on the medial femoral condyle. The test is performed by bringing the knee into 90° of flexion, internally rotating the tibia, and then slowly extending the knee. Symptoms are reproduced at approximately 30° of flexion and relieved with tibial external rotation. This test has not, however, been shown to be very specific in diagnosing OCD lesions.

A point of maximal tenderness can sometimes be found overlying the OCD lesion by gently flexing and extending the knee while applying digital pressure over the femoral condyle.

Imaging/Staging

Initial radiographs of a child who presents with signs and symptoms suggestive of an OCD lesion should include an anterior-posterior (A-P), lateral, sunrise, and tunnel view of the knee. Occasionally, a lesion that would have been missed on an A-P view of the knee is discovered on a tunnel view. This is especially common when the lesion is located on the posterior aspect of the femoral condyle, a location not adequately visualized on a standard A-P view of the knee. A skyline view helps visualize patellar or trochlear OCD lesions.

An MRI scan is now considered a routine part of the diagnostic evaluation of an OCD lesion. An MRI gives a more accurate estimate of the size of the lesion as well as the status of the overlying cartilage and subchondral bone. MRI can also be used to evaluate the stability of the lesion. Bone edema surrounding the fragment and a line of increased signal intensity at the interface of the lesion are characteristics of an unstable lesion.

When a disruption in the articular cartilage of the OCD lesion is visualized, it is important to identify whether synovial fluid has leaked behind the subchondral bone, separating it from the surrounding vital bone. This synovial fluid barrier makes nonoperative healing of the OCD lesion unlikely.

MRI can also be used to stage OCD lesions (see below). In a Stage I lesion, there is a small signal change in an area of subchondral bone without clear margins surrounding the lesion. In Stage II, the osteochondral fragment is clearly demarcated from the surrounding bone, but no synovial fluid is present between the fragment and the subchondral bone. In Stage III, there is a break in the articular cartilage, and synovial fluid partially surrounds the subchondral bone. Fluid completely surrounds the lesion in Stage IV, but the fragment is in situ. In Stage V, the fragment is completely detached and has displaced in the joint (loose body).

Stages of OCD Lesions

Stage I: Small signal change in subchondral bone without clear margins

Stage II: Clear margins surrounding lesion, cartilage is intact

Stage III: Fragmented cartilage, lesion is partially detached

Stage IV: Completely detached lesion, lesion has not displaced

Stage V: Lesion has displaced into joint (loose body)

Treatment

Nonoperative

The initial treatment of stable (Stages I and II) lesions should be conservative. This includes a period of rest from impact activities to give the knee a chance to revascularize the area of necrotic bone.

Flynn recommends a three-phase program of nonoperative treatment for OCD lesions. We follow a similar program that includes an initial period of crutch-protected partial weight bearing if the patient's knee is painful with activities of daily living. The patient may begin bearing weight as tolerated once the pain has resolved with ambulation.

At the 6-week follow-up visit, radiographs are repeated, and a physical therapy program is begun for range of motion and to strengthen and stretch the quadriceps and hamstrings. Swimming and cycling are also allowed at this point.

MRI is repeated at the 3-month visit to assess healing. If healing is progressing on MRI and the patient remains asymptomatic, the patient's physical therapy is advanced to include a sports readiness program.

Return to cutting and pivoting sports and high-impact activities is delayed for several months (usually 6 months) depending on the size and location of the lesion.

Surgical Treatment

Surgical intervention is recommended for OCD lesions that present with an unstable cartilage fragment (Stages III–V) or have been unresponsive to nonoperative treatment.

Lesions that are unstable or fail to respond to nonoperative treatment are examined arthroscopically. During arthroscopy, the cartilage is examined to determine its stability, reducibility, and integrity.

For lesions with stable cartilage, the subchondral bone is drilled to stimulate vascular ingrowth. For lesions that are unstable, the cartilage is fixed in place with bio-absorbable or metal screws. Metal screws require a second surgery for removal but are sometimes used for larger lesions where there is an increased concern for lesion stability.

Large, unsalvageable lesions are treated with fragment removal and drilling or microfracture of the subchondral bone. Drilling the subchondral bone stimulates bleeding and formation of a fibrin clot of pluripotent stem cells. These stem cells then differentiate into fibrocartilage. Fibrocartilage is similar in appearance but not as resilient to shear forces as native hyaline cartilage.

Other options for the treatment of large cartilage defects include replacement of the cartilage with osteochondral plugs harvested from non–weight-bearing areas within the joint and autologous chondrocyte implantation.

After Surgery

Postoperatively, the repaired lesion is protected by restricting the range of motion with a hinged knee brace. A safe range of motion is determined intra-operatively based on the location and postfixation stability of the lesion. A common postoperative range of motion for lesions where fixation was used is 0° to 40° for the first 2 weeks. The patient is kept on partial weight bearing for the first 6 weeks to allow for early healing. Physical therapy is started 2 weeks postoperatively. At the 6-week follow-up visit, radiographs are performed to check for early healing, and bracing and crutches are discontinued. At 12 weeks, the patient is allowed to begin to run straight ahead. Return to cutting and pivoting sports is delayed until the patient is able to run without pain and 90% of the strength of the unaffected leg has been regained.

Jeffrey Vaughn

See also Joints, Magnetic Resonance Imaging of; Knee, Osteochondritis Dissecans of the; Knee Injuries; Young Athlete

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K

Karate, Injuries in

Many people around the world practice karate, a form of martial art. There are in fact many types of martial art commonly referred to as *karate*, depending on the country in which it was developed and its accompanying philosophy. In addition to the well-known forms of karate (e.g., the traditional Okinawan and the Japanese Shotokan), there are parallel Chinese (Wu Shu and Kung Fu) and Korean (Tang Soo Do) forms. Karate practitioners, known as *karatekas,* practice their martial art mainly for defensive and spiritual purposes.

History

Karate, in Japanese, literally translates to "empty hand" or "empty fist." The island of Okinawa, historically under Japanese rule, is widely considered its point of origin, but the rudiments were evidently adapted from earlier Chinese martial art forms. Regardless of where karate originally developed, it is generally recognized that karate and other martial arts emerged all over the world as a means of self-defense. Many believe that people who were oppressed and forbidden to use any weapons developed this martial art to employ the body itself as a weapon against armed opponents.

In the United States, some U.S. soldiers who had been stationed at Okinawa following World War II and had studied karate there brought back the art with them and established schools of karate. Karate became more widely popularized with the theatrical release of the *Karate Kid* movies in the 1980s. Integrating the use of Okinawan karate in their story lines, the *Karate Kid* series did portray effectively the underlying philosophy of karate as a means of defense and as a way to develop self-discipline and a sense of spirituality.

Competition: Forms and Sparring

In addition to practicing various open-hand and kicking techniques, karatekas practice a set routine of techniques known as *forms* (*Kata*). These forms are passed on from generation to generation and sometimes altered by newer generations. The practicing of forms allows the karatekas to develop focus and discipline during practice sessions. Weapons are also integrated into certain forms. Similar to the floor exercise in gymnastics, forms is a category of competition that serves to demonstrate the karateka's skill in executing techniques.

Karate tournaments have sparring competitions with varying rules. The common type of sparring tournament employs a point-based system, with various numbers of points given for the area of body contacted or even how much contact was made (except in full-contact karate). Sweeping an opponent may or may not be allowed depending on the tournament rules. In addition, "open tournaments" allow practitioners of any style of karate to participate, in contrast to "closed tournaments," where only one style or even one major karate organization/association is allowed to participate. Sparring gear may or may not include headgear and hand and foot pads depending on the requirements of each individual tournament. Karatekas are generally required to use mouthguards. Given the lack of uniform rules regarding sparring equipment, karatekas are susceptible to injuries depending on the rules of the tournament.

Injuries in Karate

Many types of injuries can occur in karate. However, several studies have demonstrated certain patterns of injuries in karate competition. Most of the injuries sustained by karate practitioners are head and upper limb injuries. It is likely that many of the upper limb injuries sustained were due to the karateka's efforts to block attacks from opponents. Many of the head and upper limb injuries are secondary to concussions, lacerations, or hematomas.

Concussions suffered during karate competitions are handled as they would be for any contact sport. There are multiple guidelines that can be followed, but the underlying theme in all of them is to determine the severity of the concussion as well as return to activity. An event of loss of consciousness warrants consideration of a head CT (computed tomography) scan for an acute intracranial hemorrhage. Return to activity is progressive: The athlete should be asymptomatic prior to engaging in any form of exertion and should then gradually increase his or her activity. A premature return to contact sport places the patient at risk for further brain injury, in particular the often cited "second-impact syndrome." It is believed that a second concussion that occurs prior to full recovery from the previous concussion leads to life-threatening increased intracranial pressure and irreversible brain damage and/or death.

Because many karate competitions do not require the use of protective hand or foot padding, competitors are at additional risk for lacerations. Certain lacerations sustained in the head area require the skills of a specialist. For example, any laceration that involves the eyelid margin or the lacrimal drainage system of the eye should be referred to an ophthalmologist. Ear lacerations must be evaluated for cartilage involvement and repaired prior to skin closure by a skilled physician.

In general, hematomas suffered by karate practitioners can generally be treated with the application of ice, compression, and elevation of the affected extremity. It is important to evaluate neurovascular status, as well as any possibility of fracture.

In addition to the common injuries described previously, there is a specific type of contusion, called a "Karate Kid" finger, that has been reported. This injury involves the nerve located on the ulnar (medial or closer to the body) side of the little finger. This type of injury is sustained when, for strength and conditioning purposes, practitioners perform karate "chops," often on hard objects such as ice, wood, or cinder blocks. Due to repetitive trauma, scarring may occur over the underlying nerve, and constant pain or numbness is present. Surgery has been reported to be curative.

Karate Today

Today, many people enjoy the benefits of practicing karate. Whether it is for defensive purposes or for fitness and personal development, karate is one of the many martial arts that people worldwide participate in. Karate has evolved into a martial art that borrows many techniques from other martial arts, and it is now common practice to integrate more "ground-based" fighting techniques. The newer generation of martial artists may question whether karate is still relevant today as an effective martial art due to the increased popularity of Mixed Martial Arts. Many defenders of karate will refer to Lyoto Machida, a light heavyweight professional fighter who employs Shotokan karate very effectively in Mixed Martial Arts competition. In the ever-changing world of martial arts, especially with the increasing popularity of Mixed Martial Arts, many karate practitioners will experience a transformation and evolution in their training.

Arnold E. Cuenca

See also Concussions; Eye Injuries; Finger Dislocation; Finger Fractures: Bennett Fracture, Boxer's Fracture; Finger Fractures: Overview; Finger Sprain; Hand and Finger Injuries; Head Injuries; Mixed Martial Arts, Injuries in; Punch Drunk Syndrome

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Kidney, Absence of One

An athlete without a paired organ, such as a testis or a kidney, should be evaluated for participation in sports. A single kidney may be present congenitally or may be the result of surgical removal of the other kidney due to disease or trauma. It is estimated that 1 in 2,400 people are born with a single kidney.

Anatomy

The kidneys serve as a filter for the body to remove excess water and waste products from the blood. The kidneys lie in the abdomen, near the middle of the back, and are protected by fat (called *perinephric fat*) and the thoracic rib cage. Both kidneys function with extra capacity, and a significant amount of damage to the kidneys needs to occur before their productivity fails. This is why a person can survive with only one kidney.

Risk of Injury

The overall risk of injuring a kidney in team sports is quite low. Sports-related trauma to the kidneys can been estimated to be around 0.1% of all sports-related injuries based on two large studies evaluating any traumatic injury seen in a trauma center. Cycling, both recreational and competitive, was found to have the highest risk for injury to the kidney. Other sports and activities found to be of higher risk are winter sports, such as sledding and skiing, hockey, football, and equestrian events.

Injuries to the kidney are generally classified from Grade I through Grade V, with Grade IV and Grade V typically being considered higher-grade injuries. The higher-grade injuries may result in significant damage to the kidney so that surgery may be required, including complete removal of the kidney, known as a *nephrectomy*. There have been very few incidents of higher-grade renal injuries in team sports athletes, such as football or hockey players, requiring surgical management. Sports that involve higher velocities of impact, including bicycling, motocross, and winter sports such as skiing, do have a higher incidence of high-grade renal injuries. Some of these injuries have required nephrectomy; however, the risk remains quite small.

Participation in Sports

Currently, the American Academy of Pediatrics recommends that any athlete with a single kidney be individually evaluated prior to competition in sports, particularly contact sports. This may involve evaluation by a pediatrician or other general practitioner, nephrologist, or urologist. The use of protective gear may be considered, although no research has been conducted demonstrating its effectiveness in reducing renal injuries.

Mark E. Halstead

See also Physical Examination and History; Renal Injury; Young Athlete

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Kienböck Disease

Kienböck disease is an injury to the lunate, which is one of the carpal bones located in the wrist. The blood supply to the lunate is disrupted, causing damage or osteonecrosis (*osteo* = bone, *necrosis* = death). It is also known as *lunatomalacia* and *avascular necrosis of the lunate,* an injury similar to avascular necrosis of the femoral head. It can occur not only after an acute trauma but also after repetitive overuse motions. Early recognition and treatment can lead to better outcomes.

Anatomy

The lunate is one of the eight carpal bones located in the wrist. It is situated between the scaphoid (navicular) and the triquetrum bones. It also articulates with the radius (in the forearm) and the hamate and capitate (carpal bones). The blood vessels usually enter the lunate from both the palmar aspect and the dorsal aspect of the hand, but some (<20%) people have only a single blood vessel entering the palmar surface.

Causes

The cause of Kienböck disease is not known. It is thought to be caused by a single traumatic event, such as a fracture or a hard fall while playing sports, that disrupts the blood supply to the lunate. It can also be caused by repetitive motions that cause stress across the wrist, such as the swinging of a golf club or a racquet. This may cause recurrent compression of the lunate between the radius and capitate or cause shear forces across the wrist that impair the blood flow.

It is more common in people with negative ulnar variance. This is a condition where forearm bones (ulna and radius) do not have equal alignment at the wrist. The ulna is shorter than the radius, causing increased pressure on the lunate.

It is also thought to be more common in people with one blood vessel supplying the lunate.

Clinical Evaluation

Kienböck disease is best treated early in its course, so recognition and accurate diagnosis are very important. It should be considered in any athlete with wrist pain. It is usually unilateral (on one side of the body). Kienböck disease is twice as common in males and usually occurs between 15 and 40 years of age.

History

Most people will present with wrist pain and stiffness. This may or may not occur after a fall or other injury. The pain tends to gradually worsen without treatment, and it is made worse by activity, specifically with wrist movements. Typically, the wrist appears swollen. The pain may radiate up the forearm. Athletes may also complain of decreasing grip strength and trouble holding things, such as racquets, in that hand as the disease progresses.

Physical Exam

There will be tenderness and potentially swelling over the lunate. There will be decreased range of motion (ROM) of the wrist when compared with the unaffected side. This is most common with extension (moving toward the back of the hand) and flexion (moving toward the palm), while pronation and supination (turning or rotating the forearm and the hand together) are not affected. Moving the middle finger into extension (pushing it backward) will reproduce the pain. The patient may also have decreased grip strength when compared with the unaffected side.

Diagnostic Imaging

X-ray films should be obtained. Early in the disease process, they may be totally normal. However, as Kienböck disease progresses, X-rays will show sclerosis (as increased whitening) in the lunate. Eventually, the lunate becomes smaller or flattens, and the bone may fragment. Cysts may appear in the bone, and the wrist may show signs of degenerative change late in the disease process. X-rays should also assess for negative ulnar variance, which will increase suspicion of Kienböck disease (see image next page).

Computed tomography (CT) and magnetic resonance imaging (MRI) can be helpful in diagnosing Kienböck disease. A CT scan will demonstrate sclerosis and collapse in more detail and earlier

Kienböck disease in the lunate: increased sclerosis with cystic lesion

Source: Kevin D. Walter, M.D. Photo courtesy of Medical College of Wisconsin.

than X-rays. MRI can be helpful in diagnosing osteonecrosis earlier than X-rays as well.

Classification

The original classification by F. Stahl in 1947 was modified into four groups by D. M. Lichtman in 1977. The Lichtman classification remains in current use:

Stage I: This is the earliest sign of the disease. There is usually a linear fracture of the lunate seen on X-ray, CT, or MRI. The patient will usually complain only of wrist pain at this time.

Stage II: The bone will appear sclerotic or denser than usual and may begin to show a loss of height. Clinically, patients will have increased pain and often will have swelling at this stage.

Stage III: The lunate will have collapsed. This often causes other bony deformities in the neighboring carpal bones. A CT scan is needed to show the full extent of bone damage. Patients will usually have pain, swelling, and decreased wrist ROM.

Stage IV: This is the final stage of Kienböck disease. X-ray will show collapse of the lunate and generalized degenerative changes in the wrist. The patient will progress to greater loss of wrist motion.

Treatment

Immobilization can decrease motion and loading forces on the lunate but is not an effective treatment. Painkillers and anti-inflammatory medications can be used. Since Kienböck disease tends to progress even with immobilization, surgical intervention is the treatment of choice. Despite different opinions on the helpfulness of various treatments, physicians agree that early treatment is the best.

Many surgical procedures can be used to treat Kienböck disease. The surgeon will decide on the procedure that should be done based on the stage of the disease as well as ulnar variance and the wishes of the patient.

The objective of treating Stages I and II disease is to prevent further progression and to reverse damage to the lunate. Treatment of Stages III and IV disease is palliative and aimed at preventing further pain symptoms and disability.

A revascularization procedure may be done using a piece of the radius with attached pronator quadratus muscle, to attempt to create a new blood supply to the lunate bone, allowing it to heal. Revascularization can also be attempted by diverting a metacarpal artery into a hole drilled into the lunate bone after removal of the damaged bone. This usually can only be done in Stage I or Stage II, before the lunate begins to collapse.

Ulnar lengthening and/or radial shortening can also be done before the lunate collapses. These procedures attempt to level the wrist joint and take pressure off the lunate by redistributing it to other parts of the wrist. They are indicated if there is a negative ulnar variance.

There are many fusion procedures that may be done to treat Kienböck disease. During a fusion, the surgeon will remove the joints of some of the wrist bones to make them grow together into a single, larger bone. The most common is the scaphoid-trapezial-trapezoid (STT) fusion. Removal of the lunate may be necessary during a fusion. Fusion procedures may be preferred in patients with a neutral or positive ulnar variance. They are usually done in Stage III or earlier.

Lunate excision without fusion and lunate implant (silicone) are controversial and not very popular today due to potential complications, such as increased risk of degenerative change due to increased mobility of the remaining carpal bones and wrist joint irritation (synovitis) due to the silicone.

In Stage IV disease, surgical treatment is usually limited to proximal row carpectomy or removal of the scaphoid, lunate, and triquetrum. This allows patients to maintain a limited degree of wrist motion, but the wrist tends to remain functional. However, Kienböck disease may damage the joint surface of the radius and capitate, which can cause persistent pain after this procedure.

The final option is total wrist arthrodesis. This is for patients with severe degenerative change or patients who have failed other surgical procedures. This procedure fuses the entire wrist so that there is no remaining flexion or extension. This will relieve the pain but limits the function of the wrist.

After Surgery

The surgeon will discuss immobilization after surgery. Rehabilitation exercises after surgery can minimize weakness and improve strength. Return to activity and sports depends on the individual and the degree of residual dysfunction. The treating surgeon will be able to provide more insight on returning the patient to upper extremity athletics.

Kevin D. Walter

See also Avascular Necrosis of the Femoral Head; Musculoskeletal Tests, Hand and Wrist; Wrist Fracture; Wrist Injuries

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Kinesiology

Kinesiology, the science of human motion, analyzes the movements of the body and reveals the underlying biomechanical principles. Aristotle is credited with coining the term (ca. 300 BCE) and is referred to as the "father of kinesiology."

The purpose of studying clinical kinesiology is to understand the forces acting on the human body and their effects. By understanding the biomechanics and forces that act on the body, clinicians and coaches can reduce the risk and rate of injuries while optimizing the performances of the athletes.

A science of mathematical formulas and physical laws, kinesiology combines three disciplines—anatomy, biomechanics, and physiology. The integration of these studies provides the understanding of biomechanical modeling and application of motion that defines kinesiology.

Analysis of human movement is dictated by a number of biomechanical principles and laws. The most basic of these are muscle contraction and relaxation, the effect of gravity on muscle, and posture. As muscles are the principal movers of the skeletal system, they adhere to these practical laws and principles.

Biomechanical Principles of Muscle

The five basic principles of muscle action are as follows:

1. Muscles pull; they do not push.
2. Muscles contract in the center.
3. A muscle's attachment points will determine its action of on a joint.
4. Muscles create movement and/or maintain position.
5. Three types of muscle contraction are possible:
   - Shortening (concentric)
   - Lengthening (eccentric)
   - Static (neutral)

The contraction of muscle across its attached skeletal structure creates motion. Muscles contracting for the desired motions are called *agonists*, whereas the opposing muscles in those particular movements are termed *antagonists*.

The body is an excellent computer that allows for turning muscles on and off in microseconds. This sequential muscle activation allows the muscles to fire in proper sequence. A gymnast performing a back somersault completes the task in less than 1 second but uses more than 100 different muscles contracting and relaxing to perform this complex task.

Kinesiology of Posture

Muscle tissue constitutes 40% to 50% of the adult human body. Muscles are responsible for the movement, posture, and support of both the skeletal frame and the internal organs.

Our body's deeper muscle layers, found near the spine, neck, pelvis, and legs, function as antigravity muscles. These muscles contract and relax to maintain the body in an upright, erect position.

More superficially, the abdominal muscles function to support internal organs such as the liver, spleen, and stomach within the abdominal cavity.

Muscles are responsible for movement and posture. The body is supported in position by two types of postures, static and dynamic. Static posture is one of maintaining balance, whereas dynamic posture is a corrective response to movement.

Postural muscles work on constant stimuli and feedback to maintain balance. The feedback mechanism for control of these postural muscles comes from two major sources, the stretch and the righting reflexes.

The stretch reflexes are activated from those skeletal muscles that are responsible for maintaining proper tone, length, and tension to help the body maintain an upright position.

The righting reflexes control body posture. These are primitive reflexes present in infants. Newborns rely on five primitive reflexes for their basic functional movement. These help maintain righting postures. The five major primitive righting reflexes are as follows:

1. Optical righting reflex
2. Body righting reflex acting on the head
3. Body righting reflex acting on the body
4. Neck righting reflexes
5. Labyrinthine (ear) righting reflexes

These righting reflexes are important in maintaining posture and motion, especially before a child is able to stand upright or walk. The effect of these righting reflexes diminishes as the child grows, usually around 2 years, but still can be observed in adults when assessed by a trained clinician.

Kinesiology of Sport

The practical application of kinesiology has expanded the understanding of sports technique and performance. The complexity of biomechanical analysis depends on the type of sporting activity. The earliest studies relied on slow-recording film cameras for motion analysis. Thus, early kinesiological studies concentrated on simpler activity such as level walking or running, where the influences of environment and equipment were minimal. As the technology advanced with higher-frame-per-second filming, more complex motion could be more accurately analyzed in different environments. As the body can move within many different types of environments, this newer filming technology can capture the necessary data to study its motion.

The body may be studied in motion within any of these four environments or a combination of these environments:

1. The ground supports the body.
2. The body is supported by water.
3. The body is unsupported, such as falling through space.
4. The body is suspended.

In addition to filming athletic motion, other environmental factors such as air, water, and ground influences must be taken into consideration and calculated.

Kinesiological studies in water require assessing water resistance forces in the mathematical calculations. As a result of kinesiological analysis, swimming technique and performance were improved through mathematical modeling and advanced recording technology.

For an athlete performing in midair flight, elements such as gravity and air resistance forces need to be calculated in mathematical modeling. Athletes who perform off the ground, such as in gymnastics and diving, require this multidimensional analysis of their motion through space.

Kinesiology as a Predictor of Athletic Potential

The science of kinesiology has assisted coaches in identifying talent and athletic potential. Coaches have tried to identify predictors of a child's potential in developing into an elite athlete. In some countries, such as Russia and China, clinical assessment systems of selection have been implemented. Radiographic analyses of skeletal growth plates have been used to predict potential height in young gymnasts and ice skaters, since a shorter stature was believed to facilitate athletic success. In track-and-field athletes, testing muscle types and their percentages have been used to help identify and distinguish between speed and distance athletes.

A review of many sports studies found that in early childhood, physical fitness should be the focus of instruction, without specialization in an individual sport. Each sport has an optimal age period of commitment to that sporting activity. In many cases, starting the children at too young an age may be detrimental to their athletic potential and may predispose a child to leave the sport.

Gender Differences in Athletics

Gender also plays a role in athletic potential. Comparative muscle strengths have been extensively tested in males and females. Studies found that general muscle strength in the female is estimated as being two thirds that of the male. In terms of absolute strength, women were found to be weaker in their upper body strength; however, in leg strength women were actually slightly stronger when correlated equally to units of lean body weight. If muscle size were equal in the male and female, the forces exerted by the muscles would have been identical in both genders.

Hormonal differences in genders play a significant role in athletic ability. Testosterone was found to be a significant factor in promoting muscle size. Consequently, as males naturally have a greater concentration of testosterone, they are more apt to have larger muscles, or hypertrophied muscles. There have been studies that show that estrogens may play a role in increasing ligamentous laxity and predispose women toward a higher incidence of anterior cruciate ligament ruptures of the knee.

Owing to anatomical differences in genders, women are generally found to be smaller in stature and lighter in weight than males and with a lower center of balance. The center of balance for women is found at 55% of standing height, whereas in men, it is at 57% of standing height.

The pelvis size and shape also differ between males and females. The female pelvic cavity is wider in all its diameters and rounder than that of the male. Because of the wider pelvis, women have a greater tendency for knock-knees. Research has found that the wider the hips, the slower the potential speed in running.

Women generally have narrower shoulders and shorter upper arms than men. As a result of the narrower shoulder, the woman's elbow compensates with a larger carrying angle than in men, and this larger elbow angle creates a disadvantage in overhead throwing events for women.

Components of Sports Performance

Three components constitute sports performance. They are physique, physical conditioning, and psychological adaptation. When all three are optimal, one finds an elite athlete. There is little to differentiate the top level of elite athletes in any sport. As most elite players already have an athletic physique and their physical conditioning is similar, the psychological preparation may be the largest variable in their performance.

Coaches and instructors who study biomechanics and kinesiology potentially hold an advantage in optimizing their student athletes' performance. The goal of studying the athlete's biomechanics is to provide proper correction to flaws in technique that impede successful athletic performance. Understanding sports biomechanics helps eliminate the trial-and-error approach to coaching and instruction. Studying the athlete's motion allows the coach to identify the body's weakness, recognize injury-related faults, and offer corrective biomechanical solutions to these problems.

Sport kinesiology relies on the study of biomechanics. Simple and complex mathematical models and formulas have been used to describe and illustrate athletic performance in most sporting activities. In general, this mathematical modeling is a good starting point for the instructor in understanding sports mechanics. However, these models do not account for the uniqueness of each individual athlete. Each athlete is unique in flexibility, range of motion, joint mechanics, conditioning, and injury characteristics.

Identifying each athlete's variation is critical in applying a predictive model to truly understand that particular athlete's strengths and weaknesses and to decide how to maximize the athlete's performance. Golf swing mechanics is a great example of mathematical modeling. The quest for the perfect swing focused on identifying a model of optimizing acceleration. Unfortunately, most golfers have many flaws in their physique, range of motion, and flexibilities that will not allow them to duplicate a mathematical schematic model. As a result, the golf instructor is left to correct obvious swing flaws while adapting the swing mechanics to the unique physical abilities of the golfer.

Biomechanics Predict Sport-Specific Injury

Kinesiological models can identify motions or movements of increased tension or strain that can predict injury. Improper overhand throwing mechanics can lead to severe elbow injuries in baseball pitchers. Poor diving technique can lead to serious wrist injuries. Kinesiological analysis can help identify these sport-specific activities and their correlations with injury risk.

Certain sports have a characteristic pattern of consistent, well-defined injuries. A few examples are as follows:

- *Baseball:* shoulder injuries
- *Bicycling:* ulnar nerve (arm) and pudendal nerve (groin) compression injuries
- *Golf:* lower back and wrist injuries
- *Rugby:* neck injuries
- *Running:* iliotibial band syndrome and foot injuries
- *Skiing:* thumb ligament injury and anterior cruciate ligament (ACL) knee injury
- *Soccer:* groin and knee injuries
- *Swimming:* shoulder injuries
- *Wrestling:* elbow and knee injuries

Maximizing Athletic Potential: Muscle Memory

Athletic performance is often studied to maximize an athlete's potential. The study of biomechanics allows scientists and coaches to assess technique and movement. While it is important that physical trainers and educators have a good understanding of biomechanics, it is generally agreed that athletes do not require this level of scientific knowledge. The reason for withholding these complex data from the athlete is based on the idea that the athlete must act instinctively and should not be actively thinking about specific athletic action.

The value of biomechanics is demonstrated when the athlete has encoded complex muscle movement into unconscious memory. This encoding has been referred to as *muscle memory* or *mind–muscle* memory. To create mind–muscle memory, the athlete must unconsciously coordinate many muscles that are going to be needed for the task required. If the athlete is able to unconsciously perform this task, then fluidity of motion will be optimized, whereas if the athlete must think through the movement, this fluidity will be compromised. It is the ability to incorporate a complex movement into the subconscious mind that allows for the creation of mind–muscle memory.

Critics have argued that since muscles react directly to electrical stimuli, they do not have a capacity for memory. The logic states that it is the brain initiating the complex electrical sequence that activates muscle contraction and relaxation. Repeated practice of the desired motion or movement enhances memorization of this sequence, and when called on, the athlete executes this action flawlessly. This is the phenomenon of mind–muscle memory. To quote the great Baseball Hall of Fame player Roger Hornsby, a lifetime .358 hitter, "A great hitter isn't born, he's made. He's made out of practice, fault correction, and confidence."

Some athletes are easier to train than others. Those athletes who have exceptional visual motor learning abilities are the quicker learners. Prior to video instruction, those athletes who can learn through observation of elite athletes become successful in their sport. Quick hand-eye coordination is another favorable attribute that successful athletes share.

Athletic Injury

Unbalanced muscle strength can lead to strains and tears of muscle tissue. Overtraining the agonistic muscle or undertraining the antagonistic muscle increases the risk of muscular injury. In contrast, athletes who demonstrate full muscular flexibility and are proportionately strengthened and conditioned have a significantly lower incidence of strain or tear. The strain or tear usually occurs at peak muscle contraction, coinciding with peak acceleration.

Major Studies of Kinesiology

As noted earlier, kinesiology is the study of motion based on mathematical modeling and physical laws. The science of kinesiology along with biomechanics can be divided into 12 major areas of study:

1. Whole-body segmental models
2. Kinematics of movement
3. Force measurement
4. Kinetic or force-motion analysis
5. Part-body models
6. Motion of the center of gravity
7. Human–equipment interaction
8. Feedback control
9. Descriptive mechanics
10. Statistical studies
11. Physiological studies
12. Equipment design

Whole-body segmental modeling studies the way the body responds to the varying changes in body weight distribution while in motion.

Kinematics of movement is the analysis of motion across time, studying the effects of speed and accelerations on the body.

Force measurement is the essence of biomechanical study—measuring the effects of the different types of forces that act on the body through mathematical modeling and formulas.

Kinetic or force-motion analysis is the study of the body's motion response to the external forces that are acting on it. This coincides with Newton's second law: "Force equals mass times acceleration."

Part-body models examine the action of a specific section of the body, which at the most basic level is the action of a muscle across a single joint.

Motion of the center of gravity studies the relationship of the center of gravity of the body in different positions and motions.

Human–equipment interaction studies the interaction between human and machine. This type of analysis of man–equipment interactions can be very complex in mathematical modeling.

Feedback control allows the body to change its movement based on the information it receives from the body's sensory system. Scientific research in this field has been difficult, limited by our sensory technology, and overall very few studies have been published.

Descriptive mechanics is the application of technical concepts such as force, static equilibrium, work, and energy in mathematical modeling of motion.

Statistical studies involve using statistical formulations in determining whether a relationship can be consistently observed and predicted in mathematical modeling.

Physiological studies observe the effects of energy, work, and power and their relationship to exercise physiology and biomechanics.

Equipment design is primarily used by manufacturers of sports equipment. This study is extremely difficult, as one must incorporate scientific formulation with the subjective feel. As each individual athlete has his or her own subjective feel, the satisfaction of using a particular sports equipment design holds many variations. This variety of equipment is noticeably evident in golf equipment design and manufacture.

Tools of Kinesiological Study

Measuring movement and energy is now possible with the invention of high-speed cameras and sensitive sensors. The study of kinesiology and biomechanics has exponentially grown with advancements of this technology. With precise measurements, scientists can assess specific variables in athletes to help correct their weaknesses as well as to potentially optimize their performance.

Taras V. Kochno

See also Biomechanics in Sports Medicine; Sports Biomechanist

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Klippel-Feil Syndrome

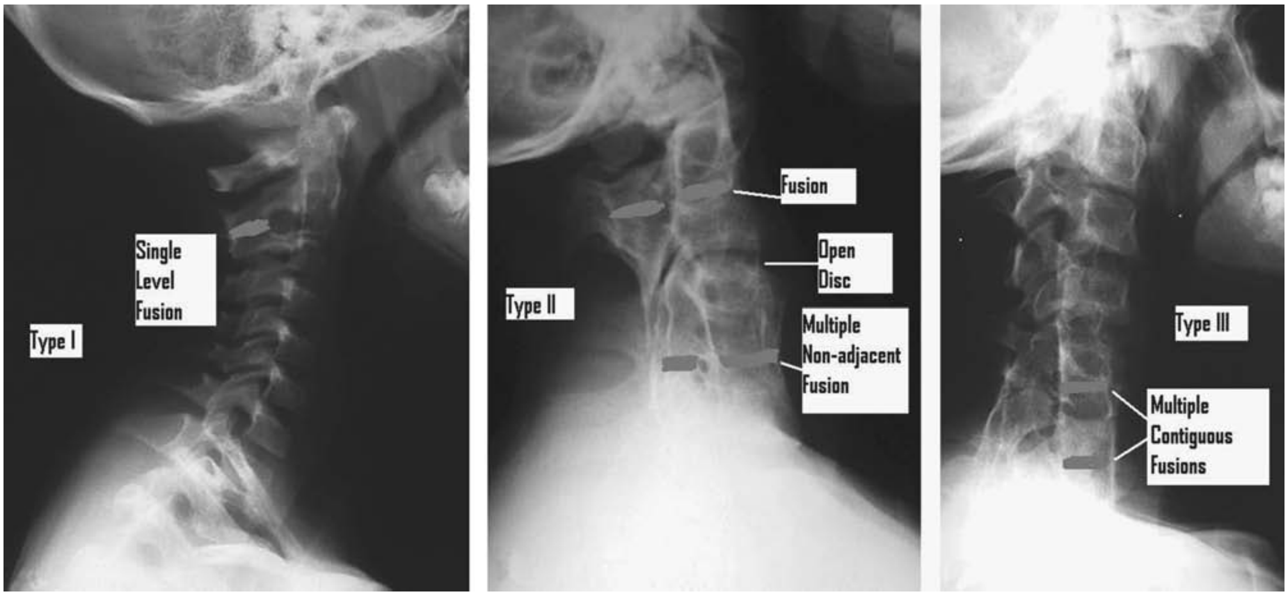
Klippel-Feil syndrome was originally described in the early 1900s by Maurice Klippel and Andre Feil. The hallmark of this syndrome involves a congenital fusion of at least two of the seven cervical vertebrae. These fusions represent incomplete separation of the cervical vertebrae during the first few weeks of life, which may indicate some fetal insult during this early development. The initial description was of individuals with a short webbed neck and a low hairline.

Klippel-Feil syndrome was originally classified into three categories. Type I involved a massive cervical spine fusion of multiple contiguous levels. Type II involved a fusion of only one or two levels. Type III included both Types I and II with associated thoracic or lumbar spine fusions. However, this classification did not necessarily correlate with development of neurologic abnormalities. Recently, a new classification of these cervical spine fusions was suggested by Samartzis and colleagues. They categorized Type I as a single-level fusion; Type II as multiple, non–adjacent-level fusions; and Type III as multiple, contiguous-level fusions (see Figure 1). This classification allows better prognostication of the development of pain and neurologic dysfunction.

Since this syndrome involves a congenital insult, other associated abnormalities include possible hearing disorders such as conductive problems of the hearing bones of the middle ear as well as sensor neural elements. Cardiac abnormalities may occur, such as a ventricular septal defect, which is a small hole in the cardiac septal division of the ventricular chambers. Urologic defects of the kidneys and collecting system may also coexist. In the musculoskeletal system, scoliosis and a Sprengel deformity are also often associated. A Sprengel deformity involves a bony or cartilaginous connection of the scapula to the cervical spine. This will limit shoulder motion. Scoliosis is an abnormal curvature of the spine when viewed from the back.

Although the classic description of these fusions involved the outward clinical appearance of a short neck, low hair line, and decreased range of neck motion, this only occurs in about 40% of cases. Often, the fusions will be noted incidentally on radiographs taken for trauma or other reasons. The motion loss may be subtle and most often involves axial rotation, which means that there will be reduced ability to turn to one side.

Participation in contact sports is one of the first concerns for many of these athletes. The major issues are instability and stenosis. Instability occurs because the disk levels above or below the fusion have excess motion to compensate for the loss at the fused level. This excessive motion will compromise the central spinal cord. Instability is most severe with high fusions that involve the craniocervical and C1-C2 junction. *Stenosis* is degenerative narrowing that occurs over time due to the excessive motion of the contiguous levels and can cause compression of the spinal cord. Stenosis is often a concern at a free level between two fusion masses. Sports considerations are discussed below.



Cervical spine fusions (Samartzis classification)

Source: Photos courtesy of Pierre A. d'Hemecourt, M.D.

Natural History

Some studies have examined pediatric and adolescent patients, while others have looked at adult patients. Klippel-Feil syndrome will present throughout life, often as an incidental finding. In the pediatric population, the majority noted at presentation are Type II (as described by Samartzis). In the adult population, Type I is the most common seen at initial presentation. The adult presents at an average age of 35, with nearly 70% complaining of some cervical spine symptoms. This is usually just neck pain and occurs less often with neurologic findings. Conversely, in the pediatric population, only 40% complained of cervical spine symptoms. The increased pain may reflect the gradual degenerative changes that occur over a lifetime.

Overall, there is a predisposition for females to have this condition more than do males. However, there appear to be more significant fusions (Types II and III) in the male population. Patients with Type I fusions will usually complain of central neck pain if symptoms occur. Although uncommon, radicular and myelopathic symptoms occur in Type II and III patients. Radicular symptoms represent pinching of the nerve roots as they exit the spine. This may manifest with radiation of pain, numbness, or muscle weakness into the upper extremities in a specific pattern to the involved nerve root. This will occur more often in Type II and III patients. Alternately, myelopathy represents a more serious injury to the central spinal cord. Manifestations of this are more nondescript, with weakness, imbalance, and spasticity of the upper and lower extremities. This is most often reported in Type III patients. The significant neurologic complaints tend to occur more in adults than in the pediatric population. This would indicate that there is a component of progressive degeneration that causes the neurologic symptoms. Similarly, patients with surgical fusions tend to have degenerative findings at the noninvolved levels, similar to Klippel-Feil patients. Furthermore, this implies that the fusions, surgical or congenital, will alter the biomechanics of the adjacent disk regions. For this reason, there is concern for the long-term consequences of repetitive-impact sport activities.

Evaluation

Musculoskeletal evaluation involves careful screening for loss of cervical motion that commonly involves rotation. Scoliosis is an abnormal curvature of the spine and has been described as a frequent association secondary to abnormal fusion of the thoracic and cervical vertebrae. A Sprengel deformity is seen in up to one third of these patients. This is suspected with a restricted shoulder range of motion. A careful neurologic examination is critical. Neurologic impairment is common when there is involvement of the upper cervical and occipitocervical juncture.

Imaging considerations are very important. Evaluation should include plain X-rays with lateral flexion and extension views to detect instability. During flexion, there may be some slippage of the nonfused segment over the fused segment. This will often correct when the spine is extended backward. This would indicate instability. Magnetic resonance imaging (MRI) is very useful in defining the amount of stenosis that is narrowing around the spinal cord. The MRI scan is also helpful in detecting associated abnormalities of the base of the brain and spinal cord. This would include herniation of the cerebellar tonsils into the spine, called an *Arnold-Chiari malformation*, and upward migration of the cervical vertebrae into the base of the skull, called a *basilar impression*. A flexion and extension MRI scan may be useful in borderline cases to define functional stenosis or narrowing that only occurs in the extremes of motion. Thoracic and lumbar plain radiographs will detect fusion masses at these lower levels.

Other evaluations include audiometric evaluations for hearing loss. A kidney ultrasound should be done to detect congenital kidney abnormalities. When cardiac murmurs are found, an ultrasound of the heart (echocardiogram) is indicated.

Return-to-Sports Considerations

Collision sports participation is the most common concern for athletes who have been detected with a Klippel-Feil fusion. The primary concern revolves around instability, with the potential for catastrophic neurologic injuries. Over time, degenerative stenosis or narrowing may occur and expose the spinal cord to critical impingement during hyperextension or hyperflexion impact activities such as football tackling. This can cause a catastrophic neurologic injury.

As such, collision sports such as football, rugby, and ice hockey are contraindicated with high fusions of the occiput-C1 and the C1-C2 vertebrae. Single-level fusions below C2 may be considered for collision activities provided there is no instability on flexion and extension plain radiographs, no stenosis on an MRI scan, no coexisting spinal cord anomalies, and clinically no pain or neurologic complaints. However, the athlete should be cautioned that repetitive impact may cause degeneration over time, with later development of instability or stenosis.

Concern should also be shown with involvement in sports that require repetitive extreme motion as the free disk spaces may again be predisposed to premature degeneration. It is known that painful symptoms occur later in adults and may reflect earlier overuse injuries. This would include sports such as soccer, which involves repetitive minor impact with a soccer ball. Proper counseling of the athlete to avoid some of these repetitive motions is appropriate.

Pierre A. d'Hemecourt

See also Cervical and Thoracic Spine Injuries; Neck and Upper Back Injuries; Sports Injuries, Overuse

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Knee, Osteochondritis Dissecans of the

Osteochondritis dissecans (OCD) *of the knee* is a focal acquired injury to the bone just underneath the cartilage of the femur. It can be thought of as a stress fracture to a small area of this bone that can progress to involve the overlying cartilage of the knee. It is most commonly present in the most athletically active children and is believed to be an overuse injury occurring from repetitive microtrauma to the bone.

Anatomy

The knee joint is the articulation between the femur (thighbone) and the tibia (shinbone). The ends of the femur and tibia are covered with cartilage that resembles the shiny smooth white end of a chicken bone. The cartilage provides a smooth, low-friction surface for the knee to allow movement. The bone directly underneath the cartilage is called the *subchondral bone*. The purpose of the subchondral bone is to support the cartilage during weight-bearing activities. The femur forms two bulbous ends in the knee joint called *condyles*, through which our weight passes. The medial femoral condyle is on the inner aspect of the knee. The lateral femoral condyle is on the outer aspect of the knee.

Causes

OCD injuries occur in athletes involved in high-impact running sports, such as soccer, football, basketball, and lacrosse. Many athletes who develop OCD injuries play multiple sports and are involved in athletic activity for many hours every day. The OCD lesions begin as a small stress-related injury to the subchondral bone. The most common location for OCD of the knee is in the posterior (back) aspect of the medial (inner) femoral condyle. This particular area of the knee receives less blood flow and is subject to high forces with activity. It is thought that repetitive microtrauma causes a small stress fracture in one area of the subchondral bone. If the overuse activity continues, the area with the stress fracture will not be able to heal appropriately and, eventually, will lose its blood supply. At this point, the subchondral bone will no longer be able to properly support the cartilage over the top of it, and if activity continues, the cartilage over the lesion will break.

Symptoms

OCD of the knee can occur in children of all ages, although it most commonly occurs in adolescents involved in multiple sports, with daily participation for several hours. It occurs most commonly between the ages of 11 and 13. It presents with aching knee pain that becomes worse with running during sports. There is usually no history of an actual fall or injury. The pain is often located at the inner or outer aspects of the knee, depending on the location of the lesion. Pain may be severe enough to cause a limp. If the overlying cartilage is cracked and injured, the knee will often swell, and mechanical symptoms such as catching or locking of the knee may be noted. In 25% of the cases, the other knee will be involved as well.

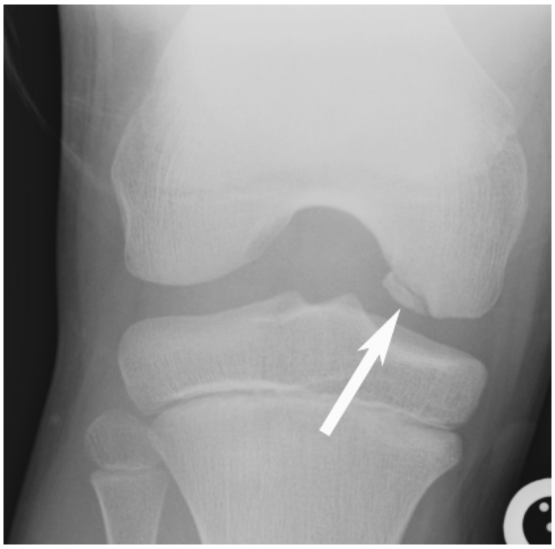
Diagnosis

An active athlete playing multiple high-impact running sports for many hours every day who presents with activity-related knee pain and swelling may have an OCD of the knee. A physical exam is the first step toward diagnosing OCD of the knee. The femoral condyles of the knee are palpated with the knee flexed to determine if there are any localized areas of tenderness. The knee is examined for signs of swelling. In patients in whom OCD is suspected, the other knee must be carefully examined, and X-rays should be obtained.

Since the lesion is most commonly located at the posterior (back) aspect of the medial femoral condyle, it is often not seen on an X-ray taken with the knee straight. Instead, a "tunnel view" X-ray with the knee flexed often best shows the lesion. On an X-ray, the OCD lesion appears as a small round crack in the subchondral bone (see X-ray, next page). The X-ray can also be used to determine if the child is still growing, as the growth plates of the femur and tibia will be visible in growing children.

The knee cartilage will not be visible on the X-rays. Therefore, a magnetic resonance imaging (MRI) scan may be obtained. The MRI scan is used to determine if the cartilage over the lesion is intact or cracked. If the cartilage over the OCD lesion is cracked, there will often be knee fluid underneath the lesion, which can be seen well on the MRI scan.

OCD lesions are classified as "stable" or "unstable." Stable lesions involve only the subchondral bone—the overlying cartilage is intact. In unstable lesions, the overlying cartilage is cracked. Making this determination is important because stable lesions tend to heal well with rest. Unstable lesions do not heal as well and if left untreated can completely break off, forming a "loose body."



Tunnel view X-ray of the knee showing osteochondritis dissecans of the femur (*white arrow*)

Source: Photo courtesy of Dennis E. Kramer, M.D.

Treatment

The two most important factors involved in planning treatment for OCD of the knee are the age of the athlete and the stability of the lesion. In general, most stable lesions in children who are still growing heal without surgery. For partially unstable lesions in growing children or for stable lesions in patients who have already grown, a short period of nonsurgical management may be attempted. However, if the lesion does not heal after 3 to 6 months, surgery is often recommended. Most unstable OCD lesions are treated with surgery. OCD lesions that persist after the patient is already grown also usually require surgery.

Nonsurgical Treatment

The most important principle for nonsurgical treatment of OCD of the knee is to stop the repetitive activities that cause the pain. This means that the athlete must be removed from most sports activities. Impact activities such as running and jumping must be completely avoided. Nonimpact activities such as swimming and low-resistance cycling are encouraged. Crutches and knee bracing are sometimes recommended during the initial stages of the treatment. Compliance with these measures is often difficult in this highly active patient population.

The initial treatment phase of rest, possibly combined with limitation of weight bearing and immobilization, usually lasts about 6 weeks. Physical therapy is then initiated, focusing on knee range of motion and strengthening activities. At periodic follow-ups, the physician ensures that the patient's symptoms are improving and may follow the appearance of the lesion with serial X-rays. Full healing of the lesion can often take anywhere from 3 to 12 months. Return to sports can take anywhere between 3 and 12 months and is allowed when the athlete is painfree and the lesion has shown signs of healing.

Surgery

Surgery is recommended for lesions that do not heal after an appropriate time period of nonsurgical management, for unstable lesions, and for lesions that persist in patients who have already grown. OCD of the knee is most commonly treated with knee arthroscopy. During arthroscopy, the surgeon will look at and use a tiny arthroscopic probe to "feel" the cartilage over the lesion. Depending on the appearance and feel of the cartilage over the lesion, the surgeon will decide on how to proceed.

In some cases, the cartilage over the lesion will be completely intact, with no cracks or fissures, and will be felt as a soft mass. In these cases, the surgeon may elect to drill tiny holes across the lesion. This technique is called *transarticular drilling,* which is done to stimulate the underlying subchondral bone to bleed in an attempt to start the healing process. If the lesion is very large or if the cartilage over the top of the lesion is cracked, the surgeon may also perform internal fixation. In these cases, metal or bioabsorbable screws or pegs may be placed across the lesion through the cartilage and subchondral bone to compress and stabilize the OCD lesion.

In some cases, the cartilage will be completely destroyed over the lesion or would have broken off to form a loose body. In these cases, the surgeon will often just remove the cartilage. The subchondral bone will then be exposed. The surgeon may then elect to perform a *microfracture procedure,* which uses an arthroscopic pick to create tiny holes in the subchondral bone. These holes will bleed, and a blood clot will eventually form over the lesion. Over time, the blood clot can repair the lesion with fibrocartilage, which although not as smooth as regular cartilage is better than leaving the bone exposed. Newer cartilage transplantation techniques are often reserved for patients who have already had the microfracture procedure done but still have pain.

After Surgery

After surgery, the patient is placed in a knee brace that limits knee motion and is instructed to use crutches. Depending on the surgeon's preference and the procedure employed, crutches and bracing may be used for 6 weeks after surgery or more. Knee motion is gradually increased over time. Physical therapy is often initiated to help the patient regain knee motion and strength. The patient is not allowed to resume impact activities until the lesion is felt to have healed. Return to sports is allowed once the patient is painfree and has regained full motion and strength and the lesion has shown signs of healing. This may take between 3 and 12 months.

Dennis E. Kramer

See also Ankle, Osteochondritis Dissecans of the; Arthroscopy; Elbow, Osteochondritis Dissecans of the

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Knee Bracing

Although considerable controversy still surrounds the use of knee bracing in the sports medicine patient, several recent randomized controlled trials have shed new light on the subject. This entry reviews the current clinical and biomechanical evidence supporting the efficacy of four brace types: prophylactic, rehabilitative, functional, and offloader knee braces. Brace-fitting techniques and tips are also presented.

Knee Biomechanics

A keen understanding of the normal biomechanics of the knee is essential to brace design, selection, and fit. Forces that are applied to the knee are resisted by an interdependent combination of muscle, ligament, meniscocapsular components, surface shape, and loading factors. The anatomic description of the knee as a simple diarthrodial hinge joint belies the very complex kinematic reality of the joint. The knee moves on six different axes and planes (Figure 1). The anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) are critical to normal knee biomechanics as they constrain and guide the femur and tibia during the arc of motion.

Brace Design

The principles underlying the design of an ideal knee brace hold true for all the categories of braces. The brace should produce a synergistic effect with the normal soft tissue knee stabilizers through a normal range of motion and should not interfere with normal knee function. It should not increase the risk of injury to other parts of the athlete's lower extremity or other players the braced athlete may come into contact with. It should protect the knee from external forces causing excess varus (bow-legged position) or valgus (knock-knee position), rotation (twisting), or anterior-posterior translation (linear motion). Finally, it should adapt to various patient shapes and sizes as well as being cost-effective.

Prophylactic Knee Bracing

Prophylactic knee braces (PKBs) are commonly used during a variety of sporting activities, including

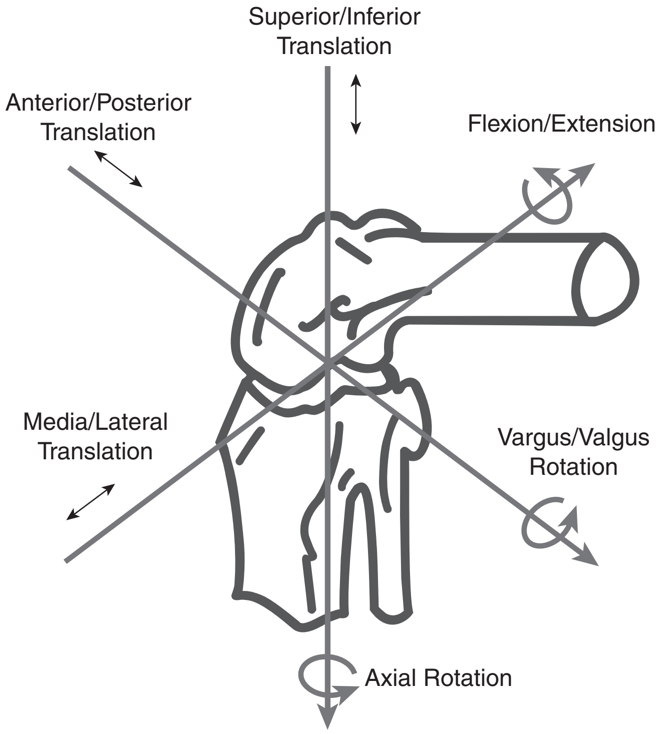

Figure 1 The Six Degrees of Knee Motion Freedom

Figure 2 Single Lateral Upright Prophylactic Knee Brace (Assist Off-the-Shelf Knee Brace, by DonJoy)

Source: Image courtesy of DonJoy.

Figure 3 Double Upright Prophylactic Knee Brace (Defiance III Custom Carbon Frame Brace, by DonJoy)

Source: Image courtesy of DonJoy.

football and soccer, in an attempt to decrease the frequency of both contact and noncontact knee ligament injuries. PKBs are commonly available in two designs. The traditional prophylactic brace has a single lateral upright with a single-axis, double-axis, or polycentric hinge at the level of the knee joint (Figure 2). A second prophylactic brace design has bilateral uprights with a polycentric hinge. The medial and lateral uprights in this latter brace have an interconnecting band (Figure 3). The results of basic biomechanical and functional studies demonstrate considerable inconsistency; however, we can still glean valuable knowledge from the results.

Prophylactic Knee-Bracing Evidence

Knee models with spring-loaded, remotely teetered steel cables have been developed to test the performance of PKBs. PKBs seem to be more effective when they allow adequate distance between the knee and its hinges and when the braces are sufficiently stiff to inhibit premature joint contact during loading. The brace ideally will disperse the force from the imparted blow away from the joint to the distal brace attachments at the thigh and calf. The PKB seems to have a more favorable protective effect for the ACL than for the medial collateral ligament (MCL) in braced patients during an impact on the outside of the knee. The brace has provided consistent protection against MCL strain in the range of 20% to 30% when compared with the unbraced knee.

Braced athletes can have a significant but reversible increase in compression of leg musculature during both activity and rest. It has been theorized that the high pressure in the leg muscles could lead to impaired blood flow and decreased performance. The performance of male football players and female lacrosse players has been examined using measures of the quadriceps muscle compression and time to muscle fatigue. Evidence suggests that females' performance scores may be more adversely affected than those of male athletes. Two well-designed prospective epidemiologic studies, the so-called West Point and Big Ten Conference studies, have been performed. Football participants in defensive positions were shown to have a significant reduction in the frequency and number of MCL injuries with brace use.

Figure 4 Rehabilitation Knee Brace (Telescoping Cool Trom, by DonJoy)

Source: Image courtesy of DonJoy.

Rehabilitation Knee Bracing

The *rehabilitation knee brace* is routinely used in the ACL-deficient, -injured, or -reconstructed knee and is recommended during the initial healing period immediately after surgery. The off-the-shelf rehabilitation or postoperative brace limits the bending arc and prevents excessive force transmission through the knee during early rehabilitation with both conservative and surgical management. To function in this context, these braces commonly contain adjustable locking hinges on both sides of the knee. The brace also contains conforming foam liners that fit the calf, thigh, and knee and nonelastic straps to secure the brace at the top and bottom (Figure 4).

Rehabilitation Knee-Bracing Evidence

A variety of rehab braces have been shown to significantly decrease the twisting, bending, or straight-line forces on the knee that are caused by an indirect stress or direct blow to the knee. Often, however, the forces used in the research setting are well below those seen in real life.

When comparing braced and nonbraced patients during postoperative rehabilitation after an ACL reconstruction, there seems to be very little difference, if any, in the subjective (patient based) or objective (external measurement based) outcomes. The knee function, knee stability, and complication rates have been noted to be similar between the braced and unbraced patients. Recently, high-quality studies using prospective, randomized controlled trials have reaffirmed these results. Braced and unbraced patients have similar activity levels, knee function, and knee stability in the long term. This has led some authors to conclude that there is no significant benefit in the use of a rehabilitation knee brace after ACL reconstruction.

Functional Knee Bracing

The *functional knee brace* helps normalize knee motion in the ACL-deficient or ACL-reconstructed knee. It should provide stability without impeding performance and act to limit abnormal knee rotational (twisting) and translational (straight line) forces that could be detrimental during sporting activities. Functional knee braces contain either straps that suspend the brace or a shell that encloses and attaches the brace to the thigh and calf. Both designs use either a unilateral or a bilateral upright, as well as a variable extension stop (Figure 5).

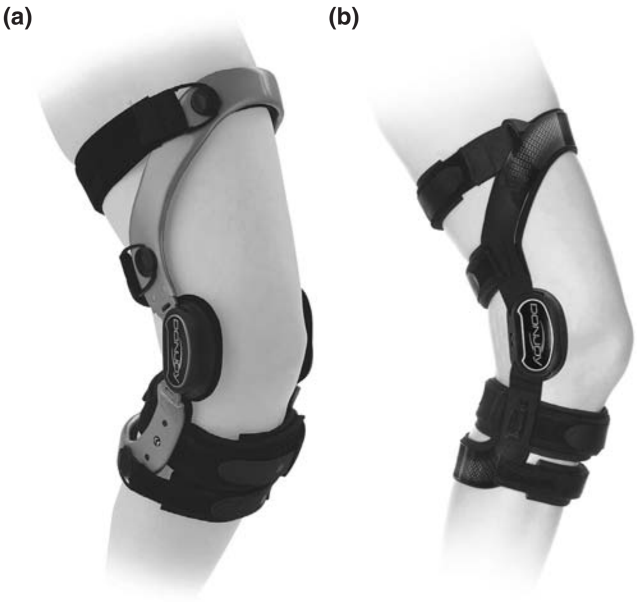

Figure 5 (a) Unilateral and (b) Bilateral Hinged Upright Functional Knee Braces (Defiance III and Full Force Knee Brace, Respectively, by DonJoy)

Source: Image courtesy of DonJoy.

Functional Knee-Bracing Evidence

Testing of braces using cadavers and artificial models in which the ACL has been severed has allowed for a detailed understanding of their ability to support and protect the knee. Functional knee bracing can improve stability by more than one third in the ACL-deficient knee by reducing the forward displacement of the tibia on the femur, a function the ACL would normally provide. There has been a concern that while the brace functions well during low-load conditions, it may not provide the same protection during a larger impact.

Evidence suggests that under subjective questioning, patients using functional knee braces report improvements that are more pronounced than would be expected from the objective experimental data. Patients reported less knee pain, swelling, and instability with brace use, as well as enhanced confidence and performance during sporting activities. Prospective, randomized clinical trials monitoring the intermediate and long-term outcomes of braced and unbraced patients have suggested that there is no significant difference in knee pain, knee joint laxity, knee range of motion, or muscle strength between the two groups. Thus, knee bracing during the postoperative period may not change the clinical outcome for young, active, ACL-reconstructed patients.

Offloader Knee Bracing

The medial *offloader knee brace* is one of an array of nonoperative treatment modalities for the management of unicompartmental knee osteoarthritis (OA). An offloader brace for osteoarthritis involving primarily the medial compartment of the knee incorporates a hinge mechanism and straps that apply a valgus force (inward-directed force toward the midline of the body) to the knee. The braces can be custom-fit or off-the-shelf (Figure 6). There is a variety of evidence on the efficacy and mechanism of function of these braces.

Offloader Knee-Bracing Evidence

Complex technology such as three-dimensional gait analysis and instrumented braces has been

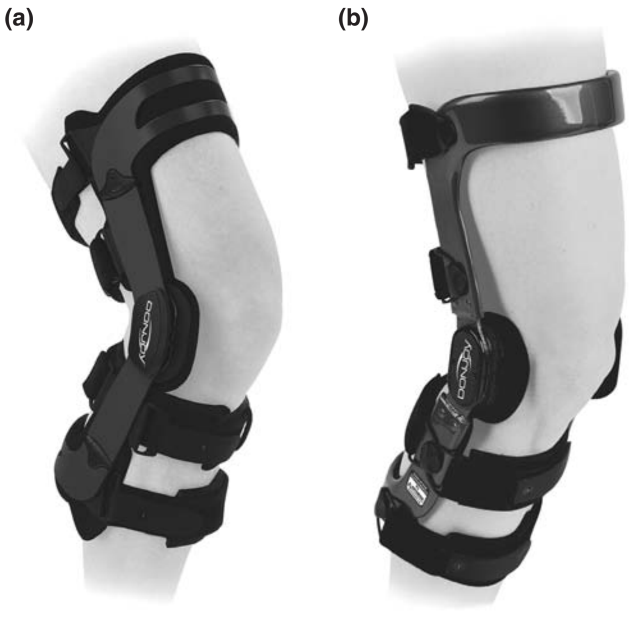

Figure 6 (a) Off-the-Shelf and (b) Custom Medial Offloader Knee Brace (OA Adjuster Off-the-Shelf Knee Brace and Defiance OA Custom Knee Brace, Respectively, by DonJoy)

Source: Images courtesy of DonJoy.

used to demonstrate the effectiveness of valgus bracing in reducing medial knee joint pressures, improving walking patterns (gait), and decreasing the malposition of the knee. Patients have consistently noted significant improvements in their knee function and gait and a reduction in the valgus knee angle during brace use.

The brace can produce a significant improvement in objective and subjective patient-based outcomes. Some studies have shown an almost 50% reduction in symptoms and a 70% improvement in function with the use of a medial offloader knee brace.

Brace-Fitting Techniques and Tips

Brace fitting is often underemphasized clinically. The treating health care team should play a key role in ensuring that the brace is appropriately fitted. To be effective, both off-the-shelf braces and custom-made braces must be specifically contoured to the soft tissues envelope of the involved limb. The primary interface between the brace and the extremity is the soft tissues of the thigh and calf. If the brace is not optimally matched to the patient's limb, poor rotational adherence and brace loosening can be a real concern. Improved translational and twisting stability can be imparted on the brace-limb construct with the use of suitable straps and by adding points of contact directly over subcutaneous bone. Contouring at the top of the tibia and adding pads to the flare of the distal femoral can help with brace fit.

Both elastic and rigid straps can be used to secure the brace. Elastic straps may provide less structural support but are much better tolerated by the patient during physical activity. Most braces have at least three or four points of fixation to maintain the brace's position. The balance between brace fit, function, and comfort must be specifically tailored to each situation, so that every patient may derive maximal benefit from the prescribed brace.

Michael A. Bridge and William D. Stanish

See also Arthritis; Knee Injuries; Knee Injuries, Surgery for

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Knee Bursitis

Knee bursitis, a common problem in athletes, can be difficult to distinguish from other knee problems. A *bursa* is a fluid-filled sac that provides a cushion and low-friction surface for tendons to glide over, thus protecting the tendon and adjacent structures. *Bursitis,* an inflammation of a bursa sac, can present in many different ways but can be classified as *acute*, *chronic*, or *septic*. Most of the time, these conditions can be treated conservatively and will do well. If suspected, a septic bursitis needs to be recognized, diagnosed, and treated expeditiously to avoid complications such as septicemia. The most commonly seen types of knee bursitis in athletes are pes anserine, prepatellar, infrapatellar, and tibial collateral.

Anatomy

The bursae of the knee are found in areas where tendons glide over bone or soft tissue. Often it is difficult to differentiate bursitis from other conditions of the knee.

The pes anserine bursa lies beneath the pes anserine tendons on the anteriomedial aspect of the inferior portion of the knee. The pes anserine tendons are composed of the confluence of the gracilis, sartorius, and semitendinosus. Beneath the pes anserine bursa lies the tibial attachment of the medial collateral ligament. The infrapatellar bursa is composed of a superficial and a deep component. The superficial infrapatellar bursa lies superficial to the proximal portion of the patellar tendon. The deep infrapatellar bursa lies deep and just proximal to the insertion of the patellar tendon on the tibia. The prepatellar bursa is a large bursa that lies directly superficial to the patella. And last, the tibial collateral bursa lies beneath the medial collateral ligament directly over the medial meniscus.

Causes

Any bursitis can be acute, chronic, or septic. Most common in athletes are the acute and chronic forms. The septic form is usually seen in older individuals, those who are immunocompromised, and those who have had trauma; it can also be iatrogenic, resulting from injection of a nonseptic bursa.

Acute bursitis is often caused by trauma, repetitive stress, gout, or rheumatoid arthritis. Chronic bursitis is often seen following single or repeated episodes of acute or septic bursitis. In addition, overuse injuries or minor repetitive trauma can also lead to this condition.

Prepatellar bursitis and superficial infrapatellar bursitis are seen in individuals who are on their knees frequently. Superficial infrapatellar bursitis, or “vicar’s knee,” is usually caused by kneeling in the upright position, whereas prepatellar bursitis, or “housemaid’s knee,” is caused by kneeling in the bent-over position. It is also more common in sports that are at risk for a direct blow to the knee, such as football and rugby. Pes anserine bursitis is often seen in individuals with an abnormal gait or knee alignment. It is also commonly seen in patients with arthritis of the knees. And last, athletes with hamstring tightness can be at increased risk for this disorder.

Symptoms

In acute or septic bursitis, the symptoms are similar. Patients will often complain of pain and swelling over the affected bursa. They may even notice increased warmth over the bursa. In addition, the patient will often have pain and limited range of motion when the tendon overlying the bursa is active. For example, with prepatellar bursitis they will have pain and limited range of motion with flexing or extending the knee. With septic bursitis, the pain with range of motion is often more pronounced and is often associated with fever and chills.

In chronic bursitis, often patients will have minimal to no pain. They may present with chronic or increasing swelling of the involved bursa that has occurred over weeks to months. Chronic bursitis will not have redness or warmth associated with it. If the bursa has become distended, patients may have minor discomfort with range of motion.

Diagnosis

The diagnosis of knee bursitis can usually be made by a history and physical exam. The constellation of the history of trauma, overuse, repetitive kneeling, or other risk factors discussed above can help make the diagnosis. In acute or septic bursitis, the exam will often show swelling, erythema, and warmth over the affected bursa as well as tenderness to palpation. If fever is present, then it is diagnosed as septic bursitis. In chronic bursitis, the clinician will usually be able to appreciate swelling over the affected bursa, but it will not be associated with erythema or warmth. Tenderness to palpation can be variable with chronic bursitis but will be minimal if present.

On exam, differentiating acute bursitis from septic bursitis can be difficult. An open wound or penetrating trauma would suggest septic bursitis. If one cannot differentiate acute from septic bursitis, then the bursa needs to be aspirated. The fluid should then be sent to the laboratory and tested (blood cell count, microorganisms, Gram stain, and presence of crystals). The white cell count in septic bursitis can be lower than that seen in septic arthritis. If a threshold of >2,000 cubic millimeters of white blood cells is used, it will give a sensitivity of 94% and specificity of 79%. The examination of the fluid for crystals will help rule out gout or pseudogout.

Deep infrapatellar bursitis can be difficult to differentiate from other disorders of the knee such as Osgood-Schlatter disease and patellar tendinitis. Tenderness to palpation is superior to the tibial tubercle and deep to the patellar tendon. Tibial collateral ligament bursitis can be difficult to differentiate from a medial meniscus tear, as they will both create tenderness over the medial joint line. The absence of an injury to the knee makes the diagnosis of tibial collateral ligament bursitis more likely.

Imaging can play a role, especially to help differentiate bursitis from other conditions or to rule out a retained foreign body in cases of trauma. Plain X-ray can be useful to see a foreign body or to evaluate for other conditions such as Osgood-Schlatter disease. Magnetic resonance imaging, computed tomography, or ultrasound can be used in cases where the diagnosis is not clear-cut, such as in differentiating tibial collateral ligament bursitis from a medial meniscus tear.

Treatment

Most knee bursitis can be treated conservatively. Rarely do these conditions require surgical intervention.

Nonsurgical Treatment

In acute prepatellar bursitis, initial treatment with rest, ice, compression, immobilization, and nonsteroidal anti-inflammatory drugs (NSAIDs) is often effective. Immobilization should only be used for short periods. In knee bursitis, the decision to aspirate and inject the bursa with steroids depends on the degree of swelling, which bursa is involved, and the need for quicker return to play. If septic bursitis is not ruled out, a steroid should not be injected. The prepatellar bursa is the most commonly aspirated, but if it is swollen enough, the infrapatellar bursas can be aspirated. Typically, the pes anserine and tibial collateral ligament bursa are only injected and not aspirated. A bursa aspiration or injection should be done under sterile conditions so that acute bursitis does not become septic. After aspiration, the knee should be immobilized and a compressive dressing applied (see Figure 1). In chronic bursitis, avoidance or protection against the aggravating activity, for example, kneeling, can help reduce the swelling. If symptoms persist, aspiration followed by an injection of steroid can be helpful.

Septic bursitis is treated similarly as acute bursitis but with the addition of an antibiotic and without the injection of a steroid. In the knee, it is rare to have septic bursitis except in the prepatellar bursa. If the symptoms are mild and the patient has no systemic symptoms, oral antibiotics can be used. Recommended antibiotics would be a penicillinase-resistant antibiotic or a first-generation cephalosporin, such as cephalexin. In penicillin-allergic patients, clindamycin can be used. If there

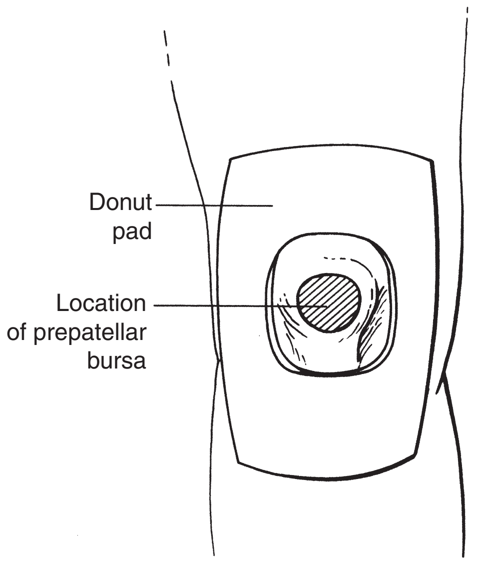

Figure 1 Use of Donut Pad to Compress Bursa

is a concern for methicillin-resistant *Staphylococcus aureus* (MRSA), then trimethoprim-sulfamethoxazole or clindamycin can be used. In case of severe infection, failed oral antibiotics, or an immunocompromised patient, hospital admission and intravenously administered vancomycin are recommended until the culture and sensitivities are back. Duration of therapy depends on the clinical response, but often 2 to 3 weeks of treatment with antibiotics is required. In addition, daily knee aspiration is usually adequate for drainage.

Surgical Treatment

In recalcitrant cases of chronic bursitis or recurrent septic bursitis, excision of the bursa is indicated. In septic bursitis, surgery is warranted if the bursa cannot be adequately drained with a needle, if a foreign body is present in the bursa, if there is a need for debridement of adjacent structures, or if antibiotic therapy is failing. In these cases, the bursa is opened, drained, and washed out. A drain can also be placed if necessary.

Prognosis

Most cases of knee bursitis do well with conservative treatment regardless of whether the bursitis is acute, septic, or chronic. The rare cases in which surgery is necessary usually do well.

Michael A. Krafczyk

See also Cyst, Baker; Iliotibial Band Syndrome; Knee Injuries; Osgood-Schlatter Disease; PRICE/MICE; Wrestling, Injuries in

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Knee Injuries

Knee injuries are common in sports, particularly in the pediatric age-group. In the United States, there were 229,298 knee injuries reported in children under 18 years of age in 2001. This is likely an underestimate as many injuries are not reported and many others are seen by family doctors or in walk-in clinics, which do not report injuries. The incidence has been steadily increasing. The most common sports-related injuries resulting in permanent and long-term morbidity are knee injuries. Knee injuries are seen most commonly in sports that involve twisting movements and rapid changes in direction, such as American football, basketball, and skiing.

Both acute and chronic or overuse knee injuries are seen in athletes, resulting from sports participation. Acute knee injuries, such as ligament tears or meniscal tears, occur frequently in basketball, hockey, skiing, soccer, and football. Overuse knee injuries, such as Osgood-Schlatter disease or patellofemoral pain syndrome, are seen frequently in running and jumping sports. Chronic anterior knee pain is a very common presenting complaint in the sporting population.

Risk factors for knee injuries are listed in Table 1. These include both intrinsic and extrinsic factors. Intrinsic factors are anatomical and inherent factors that may not necessarily be modifiable. Extrinsic factors are associated with biomechanical and environmental issues that may be more easily modified.

Anatomy

The bony anatomy of the knee includes the femur superiorly, the tibia inferiorly, and the patella

Table 1 Risk Factors for Knee Injuries

Intrinsic Factors	*Extrinsic Factors*
Female gender	Excessive loading to knee (single event or recurrent)
Q angle	Poor training techniques, conditioning
Knee malalignment (genu valgus/varus)	Poor coaching/supervision
Limb length discrepancy	Improper use of equipment/not wearing appropriate equipment
Poor muscle flexibility	Type of activity
Patellar hypermobility	Warm-up and stretching
Previous injury	
Inadequate rehabilitation of injury	
Age	
High body mass index (BMI)	
Low level of physical fitness	

anteriorly. The proximal fibula articulates with the tibia but not the femur. The medial and lateral prominences of the distal femur are known as the *medial* and lateral *femoral condyles*. The depression between the condyles is the intercondylar notch or trochlear groove. This is where the patella articulates with the femur. The tibial plateau is the flared articular surface of the tibia, and the tibial spine is the bony eminence in the center of the tibial plateau.

There are several ligaments in the knee joint, including the anterior cruciate ligament (ACL), the posterior cruciate ligament (PCL), the medial collateral ligament (MCL), and the lateral collateral ligament (LCL). The ACL originates from the medial aspect of the lateral femoral condyle and inserts on the anteromedial area of the tibial plateau. The main function of the ACL is to prevent the excessive anterior translation of the tibia on the femur. The PCL originates at the lateral aspect of the medial femoral condyle and traverses behind the ACL, inserting on the posterolateral area of the central tibial plateau. The PCL functions to prevent excessive posterior translation of the tibia on the femur. The MCL originates on the distal medial femoral condyle and inserts on the proximal tibial epiphysis. The MCL protects the knee against excessive valgus force. The LCL originates on the lateral femoral condyle and inserts on the proximal fibular head. The LCL protects the knee against excessive varus forces (Figures 1a and b).

Other important structures in the knee joint are the menisci. The medial meniscus (MM) and the lateral meniscus (LM) are C-shaped masses of hyaline cartilage located on the medial and lateral surfaces of the tibial plateau. The menisci act as shock absorbers that protect the knee from high mechanical loads. They also contribute to joint lubrication and nutrition.

There are two main muscle groups affecting knee function. The quadriceps muscle group in the anterior thigh extends the knee. There are four muscles constituting the quadriceps muscle group: the vastus lateralis, vastus medialis obliquus, vastus intermedius, and rectus femoris. The vastus lateralis, medialis, and intermedius all originate on the proximal femur and insert on the patella via the quadriceps tendon. The rectus femoris originates on the anterior iliac spine, crosses both the hip and the knee joint, and inserts on the tibial tubercle via the patellar tendon.

The hamstrings muscle group, in the posterior thigh, flexes the knee. The hamstrings consist of the short and long heads of the biceps femoris, the

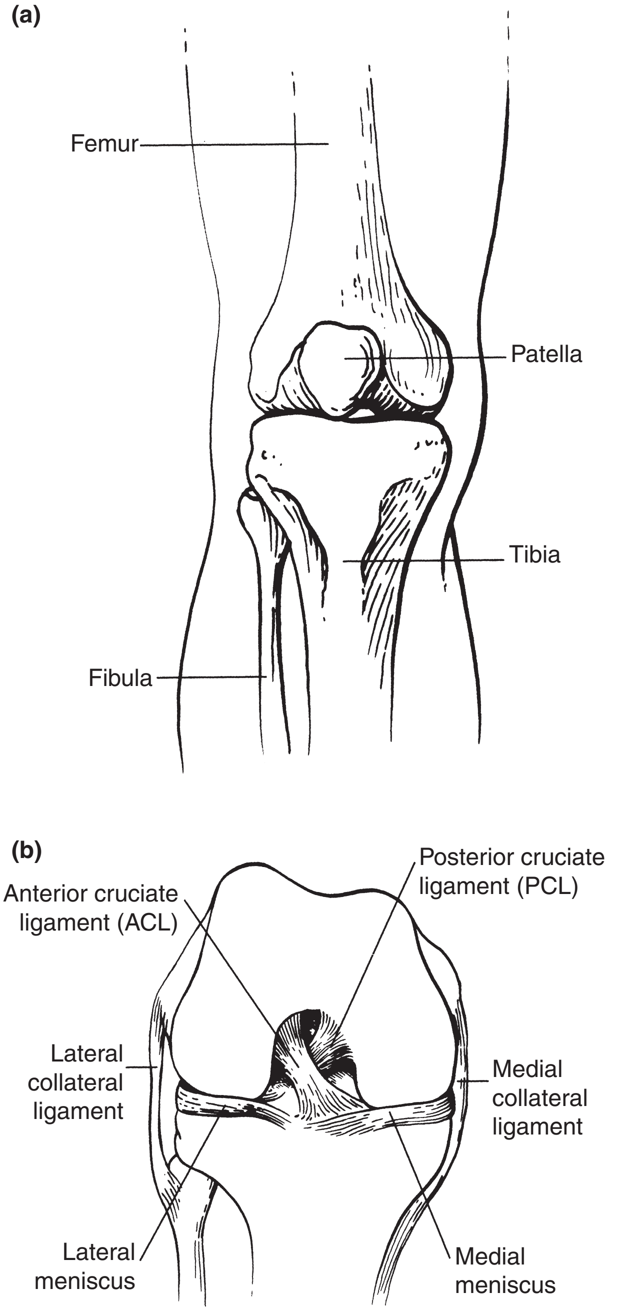

Figure 1 (a) The Knee Joint and (b) Ligaments of the Knee

semimembranosus, and the semitendinosus muscles. The hamstrings originate on the ischial tuberosity. The biceps femoris inserts on the head of the fibula. The semimembranosus and semitendinosus insert medially on the proximal tibia. Other muscles contributing to knee flexion include the sartorius and gracilis muscles, as well as the plantaris, gastrocnemius, and popliteus muscles. The sartorius and gracilis muscles originate in the pelvis and cross the knee medially to insert on the medial aspect of the proximal tibia. The popliteus, plantaris, and gastrocnemius muscles originate on the distal femur and cross the knee posteriorly. The iliotibial band (ITB), a tight band of fascial tissue, crosses the knee laterally. The ITB originates from the tensor fascia latae, gluteus medius, and gluteus maximus muscles and inserts at the Gerdy tubercle, just lateral to the tibial tubercle.

In young athletes who are still growing, the long bones have open growth plates, where new bone is formed. The proximal tibial growth plate and the distal femoral growth plate contribute more than half of the longitudinal growth for these bones. Other sites of bone growth are the sites of attachment of tendons, called *apophyses*. In the knee, there are four apophyses: the tibial tubercle, the inferior patellar pole, the superior patellar pole, and the superior-lateral aspect of the patella. The patellar tendon attaches superiorly at the inferior patellar pole and inferiorly at the tibial tubercle. The quadriceps tendon attaches to the superior aspect of the patella. The growth plates and apophyses are susceptible to injury, which may affect the growth of the athlete.

Evaluation of Injuries

Details of Injury

The key to a correct diagnosis of a knee injury rests on an accurate description of the presenting complaint and the mechanism of injury. An athlete with a knee injury may have pain, instability, or swelling. The mechanism of injury may help determine what injury has occurred. The location of pain also helps delineate the exact injury. An important diagnostic clue is the degree and timing of swelling. Significant swelling that occurs within the first 1 to 2 hours postinjury indicates a hemarthrosis (bleeding into the joint), which is usually associated with a major ligament rupture (ACL, PCL), a patellar dislocation, or a fracture. An effusion that occurs over several hours or the next day is more indicative of a meniscal injury.

Athletes will sometimes volunteer that they heard a “snap” or a “pop” at the time of injury or had the sensation of something having “moved” or "popped out" at the time of injury. This is usually associated with an ACL rupture or a possible patellar dislocation.

There may be mechanical symptoms, such as clicking, locking, or giving way, associated with a knee injury. Clicking or locking is classically associated with a loose body or a meniscal tear. Locking refers to significant loss of passive range of motion, particularly extension. Giving way can occur with instability, loose bodies, or muscle weakness. It can also be related to pain.

Previous injuries to the knees, including previous surgeries, can make athletes more susceptible to further knee injuries. Management of knee injuries may depend on the athlete's age, occupation, and sports and leisure activities and the level of sports played, as well as particulars of training, including frequency and any recent changes to the training regimen. Current and future goals of the athlete can also help determine treatment.

In the absence of an acute traumatic event, there may be other causes of knee pain. Multiple swollen joints, fevers, night sweats or night pain, or changes in weight or growth may indicate an infection, arthritis, or cancer as a cause of knee pain.

Physical Findings

An athlete with a knee injury may be unable to put full weight on his or her injured leg and may walk with a limp. The alignment of the legs can predispose an athlete to injury. Common alignment abnormalities include bowlegs (genu varum), knock-knees (genu valgum), knees that bend backward (genu recurvatum), flat feet (pes planus), kissing/squinting kneecaps, and femoral anteversion (rotation of the femurs). Range of motion of the injured knee may be decreased compared with the uninjured knee. Range of motion of the hip may also be decreased in situations where a hip injury causes knee pain.

An injured knee may be swollen, bruised, or deformed. There may be atrophy or asymmetry of the muscles around the knee. The presence and amount of joint effusion can be assessed by milking the joint. The examiner's right hand occludes the suprapatellar bursa, and the left hand milks any excess joint fluid across the joint from the lateral to the medial side. A bulge of fluid seen at the medial aspect of the knee is consistent with an effusion.

Tenderness to palpation may indicate the type of injury. With the knee in flexion, the medial and lateral femoral condyles can be palpated. Tenderness in this area suggests an osteochondral injury, such as fracture or osteochondritis dissecans. The medial and lateral joint lines can also be palpated with the knee in flexion. Tenderness along the joint lines indicates meniscal injury. The kneecap may be tender to the touch at the lateral, superior, medial, or inferior areas in patellofemoral pain syndrome. Areas of bone growth (apophyses), including the tibial tubercle and the inferior pole of the kneecap, may be tender to palpation in the setting of apophysitis, such as Osgood-Schlatter and Sinding-Larsen-Johansson syndromes. The patellar tendon, MCL, and LCL may also be tender to palpation.

There are a number of special tests to assess injuries to the knee. The anterior drawer, Lachman, and pivot shift tests assess the integrity of the ACL. The anterior drawer test is performed with the patient in the supine position with the knee flexed to 90°. The patient's lower extremity is stabilized by sitting on the foot. The proximal tibia is held with both hands, and as the hamstrings relax, the examiner attempts to glide the tibia forward. With an intact ACL, there is a firm end point. A positive test is obtained when there is more glide on the affected side than on the unaffected side. With experience, a "soft" end point is appreciated.

The Lachman test is also performed with the patient lying supine with the legs extended. One hand stabilizes the distal femur while the other hand attempts to glide the tibia forward with respect to the femur. Excessive glide indicates ACL incompetence. Comparison with the uninjured leg is important, particularly in children and adolescents who may have ligamentous laxity.

The pivot shift test is performed with the patient supine. With the tibia internally rotated and the knee fully extended, a valgus stress is applied to the knee as the knee is flexed. If the ACL is torn, the femoral condyles will be subluxated. As the knee is flexed, the examiner looks for a "clunk" as the tibia reduces (positive pivot shift). The knee is then extended, noting any click into subluxation (positive jerk test).

The posterior drawer test and posterior sag test assess the integrity of the PCL. For the posterior drawer test, the patient is positioned as for the anterior drawer test. However, the tibia is forced posteriorly with respect to the femur. A positive test is indicated by excessive posterior glide of the tibia. Again, comparison with the uninjured leg is helpful. The posterior sag test is performed with the patient supine, with the knees flexed to 90° and the patient relaxed. The position of the tibia relative to the femur is observed. A positive test is indicated by a relatively posterior position of the tibia.

Meniscal injuries are assessed with McMurray and Apley tests. The McMurray test is performed with the patient lying on his or her back with the legs extended. One hand holds the heel of the injured leg and flexes the knee. The other hand is placed on the knee with the fingers along the medial joint line and the thumb along the lateral joint line. The knee is alternately externally and internally rotated and extended while a valgus force is applied. A positive test results when pain is elicited or the examiner feels a click or pop in the joint.

The Apley test can be performed when there is confusion about whether medial knee pain is coming from an MCL injury or a meniscal injury. In both MCL injuries and medial meniscal injuries, palpation of the medial joint line can reproduce pain. The Apley is a two-part test. The first part is the compression test, which assesses for meniscal injury. The Apley compression test is performed with the patient lying in a prone position with the injured knee flexed to 90°. The heel is held, and an axial load is applied while rotating the tibia externally and internally on the femur. Pain is elicited along the joint line if there is a meniscal tear. The second part of the Apley test is the distraction test. The examiner applies traction on the lower leg while twisting it. A positive test elicits pain along the medial aspect of the knee.

The collateral ligaments are assessed with the patient lying supine. One hand applies a valgus (toward midline) stress to the injured knee at 0° and 30° of flexion while the other hand applies a counterforce to the ankle. This stresses the MCL. A positive test elicits pain or laxity along the medial aspect of the knee. A varus (away from midline) force is then applied to the knee at 0° and 30° of flexion, with a counterforce applied at the ankle. This stresses the LCL. A positive test elicits pain or laxity at the lateral aspect of the knee.

The Ober test assesses the tightness of the ITB. The patient lies on the uninjured side with the injured leg abducted at the hip. If the ITB is tight, the hip will be unable to passively adduct past an imaginary horizontal line.

The kneecap may be injured in sports. Injuries to the kneecap can make the athlete feel as if the kneecap is unstable. The stability of the kneecap can be assessed by a patellar apprehension test. The athlete lies on his or her back with the legs extended. The examiner places both thumbs along the medial aspect of the kneecap with the index

Table 2 Ottawa Knee Rule

A knee radiograph is indicated after trauma when one of the following is present:

- patient age is more than 55 or less than 18 years
- tenderness at the fibular head
- tenderness over the patella
- inability to flex the knee to 90° (hemarthrosis, fractures)
- inability to weight bear for four steps at the time of injury and when examined

Source: Reprinted with permission from Stiell IG, Greenberg GH, Wells GA, et al. Prospective validation of a decision rule for the use of radiography in acute knee injuries. *JAMA*. 1996;275(8):611–615.

Table 3 Acute Knee Injuries

Common	*Uncommon*
ACL tear	LCL sprain
MCL sprain	Patellar tendon rupture
Meniscal tears	Quadriceps rupture
Patellar dislocation	Fracture of tibial plateau
Contusions	Avulsion fracture of tibial spine
	Osteochondritis dissecans
	Bursitis
	Avulsion of biceps femoris tendon

Note: ACL = anterior cruciate ligament; LCL = lateral collateral ligament; MCL = medial collateral ligament.

fingers along the lateral patella. With the athlete's quadriceps muscles relaxed, and watching the athlete's face, lateral force is applied to the patella with the thumbs in an effort to move the patella. Patients who have had a previous patellar dislocation or subluxation will become apprehensive as the patella moves laterally.

Investigations

X-rays should be performed in cases of acute trauma, particularly if swelling is present, to assess for fractures. A set of decision criteria to determine the need for knee X-rays, known as the *Ottawa knee rule*, was developed in the 1990s (Table 2).

A computed tomography (CT) scan may be used to further delineate fractures, particularly if X-rays do not indicate an obvious bony injury. A CT scan also may be helpful to look for loose bodies.

Magnetic resonance imaging (MRI) is helpful as an adjunct to clinical assessment when the diagnosis is uncertain. MRI is useful to assess meniscal injuries; ligament tears, particularly ACL tears; articular cartilage damage; and some bony injuries, such as osteochondral edema (bone bruise) and osteochondritis dissecans.

Ultrasound can examine the patellar tendon as well as bursal swelling. It can also be used to assess meniscal cysts.

Arthroscopy (camera scopes introduced into the joint through the skin) can be used as both an investigation and a treatment. In cases where the diagnosis is uncertain, diagnostic arthroscopy can help clarify the problem. The clinician can usually treat the injury at the same time.

Types of Injury

Tables 3 and 4 provide a list of acute and chronic knee injuries.

Prevention of Injury

Not every injury can be prevented in a sport setting, but some guidelines may help prevent some injuries. Sport safety is essential to help reduce the incidence of injury. Appropriate safety equipment for a particular sport should be worn and replaced

Table 4 Overuse or Chronic Knee Injuries

Area of Knee	*Common*	*Uncommon*
Anterior	Patellofemoral pain syndrome Patellar tendinopathy Osgood-Schlatter disease Sinding-Larsen-Johansson disease Patellar subluxation	Pre-patellar bursitis Quadriceps tendinopathy Osteochondritis dissecans Slipped capital femoral epiphysis (SCFE) Legg-Calvé-Perthes disease
Posterior	Biceps femoris tendinopathy Referred pain from back, patellofemoral joint	Baker cyst Popliteus tendinopathy Gastrocnemius tendinopathy Posterior cruciate ligament (PCL) sprain Deep vein thrombosis
Medial	Patellofemoral pain syndrome Medial meniscus tear, degenerative changes, cyst	Synovial plica Pes anserinus bursitis Osteoarthritis of medial knee compartment Referred pain from back and hip
Lateral	Iliotibial band friction syndrome (ITBFS) Lateral meniscus abnormality (tear, degenerative changes, cyst)	Osteoarthritis of lateral knee compartment Biceps femoris tendinopathy Patellofemoral pain syndrome Referred pain from spine and hip

as necessary. Surfaces and equipment should be well maintained according to safety regulations. The rules of the sport should be adhered to. Proper sporting techniques should also be emphasized to avoid injury. For instance, balance training may help reduce ACL injuries in cutting sports.

Preparticipation evaluations prior to the start of a sporting season can help identify potentially modifiable factors to help prevent injuries. In particular, any previous injuries and muscle imbalances or inflexibilities can be assessed and appropriate rehabilitation instituted before the season gets under way.

General fitness is also essential to reduce injury. Athletes should maintain a general level of fitness year-round. Participating in a variety of activities, particularly during the off-season, is helpful to achieve global strength and fitness. It is important to have an off-season from a sport to allow for adequate rest of the muscles used repetitively during the season. Athletes shouldn't participate in the same sport all the year round. Although there are no specific exercises that have been shown to reduce knee injuries, athletes should continue a general strengthening and conditioning program that is complementary to their chosen sport. In addition, warm-up and cooldown sessions, with stretching exercises, should be done prior to and after playing sports.

During a sport season, it is important not to overtrain. Adequate recovery time and rest are essential to allow the body to recuperate. Attention should be paid to the frequency, duration, and intensity of training to ensure that the training program does not exceed the athlete's abilities.

In children and adolescents, additional measures to prevent injury include modifying the standard rules of the games for specific age-groups, shorter periods of activity, modifying the court or field size for various ages and skill levels, and matching opponents in size and skill level to provide safe, level fields of engagement. Emphasis in sports should be on skill development and having fun rather than on winning at all costs. Adequate adult supervision and officiating, as well as proper coaching, should be ensured.

Return to Sports

Return-to-play guidelines following a knee injury are specific to the particular injury. In general, athletes should have regained a baseline level of conditioning before returning to sports and participating in practices and drills. Most athletes should be able to continue to participate in some aspect of their sport while an injury is healing. Athletes should progress from general strengthening and conditioning to sport-specific rehabilitation exercises. Once the athlete has mastered sport-specific exercises, gradual return to play can be initiated. Athletes should continue to wear any prescribed brace or support until advised otherwise by the treating therapist or physician.

Laura Purcell

See also Biceps Tendinitis; Extensor Mechanism Injury; Knee, Osteochondritis Dissecans of the; Knee Ligament Sprain, Medial and Lateral Collateral Ligaments; Meniscus Injuries; Osgood-Schlatter Disease; Patellofemoral Pain Syndrome; Q Angle

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Knee Injuries, Surgery for

The knee is one of the most commonly injured joints of the body. In sports, meniscal (spacer cartilage in the knee) tears, anterior cruciate ligament (ACL) tears, and patella (kneecap) injuries are common major injuries. Fractures of the bones of the knee are less common but occur in sports with high-energy activity, such as motorcycle racing and skiing. For many traumatic injuries to the knee, surgical treatment is necessary. Overuse injuries occur much more frequently than traumatic injuries and are generally treated without surgery. Sometimes, nonoperative treatment fails, and surgery is necessary to resolve an overuse condition.

Anatomy and Function

The knee is mostly a hinge joint. It also functions as a ball-and-socket joint to some extent. (For an illustration of the anatomy of the knee joint, see the entry Knee Injuries.) At the end of the femur (thighbone), there are two rounded condyles covered with slippery smooth cartilage. On the other side of the hinge is the tibia, with two matching hollow areas also covered by smooth cartilage. Allowing the femoral condyles to more perfectly match the flatter tibia are two crescent-shaped cartilages on either side. These are the menisci, medial and lateral, whose job is to provide a better fit and some cushioning and to help distribute joint fluids. Holding the knee together are four main ligaments: the medial and lateral collateral ligaments (MCL and LCL, respectively) and the anterior and posterior cruciate ligaments (PCL). The ligaments provide static restraint to abnormal motion.

The muscles that control and stabilize the knee are the quadriceps group in front to straighten the knee and the hamstring group at the back to bend or flex the knee. In addition, the gastrocnemius calf muscles help bend the knee. When the quadriceps contracts concentrically, it shortens, straightening the knee as in jumping. The hamstrings shorten concentrically during sprinting to strongly flex the knee. Muscles also work by contracting against forces that are trying to lengthen the muscles. This is eccentric contraction, and for the quadriceps, it occurs when landing from a jump. The muscles actively stabilize the knee and absorb the forces around the knee.

The patella (kneecap) is a bone within the tendon of the quadriceps and serves three purposes: (1) it protects the rest of the knee joint from trauma; (2) it elevates the quadriceps tendon, giving the muscle increased mechanical force; and (3) it provides a gliding cartilage surface over the end of the femur, protecting the tendon. The patella has the thickest cartilage in the body and bears the highest loads.

Knee Injuries

When forces bend the knee in ways it was not designed to go, ligaments tear. If there is compression or twisting within the knee, meniscus tears can occur. A direct blow to the patella can dislocate it to the side. An indirect twisting motion of the knee can also cause the patella to dislocate. Blunt force to any bone can break or bruise the bone. Most injuries involve a combination of forces, so that in landing incorrectly from a jump, an athlete can have abnormal compression on one side of the knee, abnormal distraction forces on the opposite side, and a twisting component to the injury as well. Such an injury can result in meniscus tear, bone bruising, surface cartilage injury, and tears to the collateral and anterior cruciate ligaments. The orthopedic surgeon depends on the history, the physical examination, and studies such as magnetic resonance imaging (MRI) to determine the extent of injury and what is necessary to repair all structures.

There are many knee problems that are treated with surgery. Some of the more common injuries include meniscus tears and ACL tears. Patella dislocation is not necessarily treated surgically, but frequently, there is a loose piece of bone or patella instability, and surgery is required. Overuse knee injuries that require surgery include patella overload problems, osteochondral stress fracture (osteochondritis dissecans), and chronic inflammatory or degenerative problems of cartilage, synovium, or tendon.

Surgery of the Knee

Decision Making

In most cases, the decision of whether or not surgery is necessary is not a simple yes or no. For example, a torn meniscus does not automatically mean an operation is necessary. In a young athlete with a small tear without symptoms, the tear may simply be allowed to heal. In an older athlete with knee osteoarthritis, there are frequently meniscus tears that are completely symptom-free, and surgical removal can actually make the patient worse.

The best surgeons use specific guidelines to help them make their decisions. These are no typically written guides but rather known sequences to follow depending on various parameters. They result in specific recommendations by the surgeon based on the variables associated with the particular injury at hand.

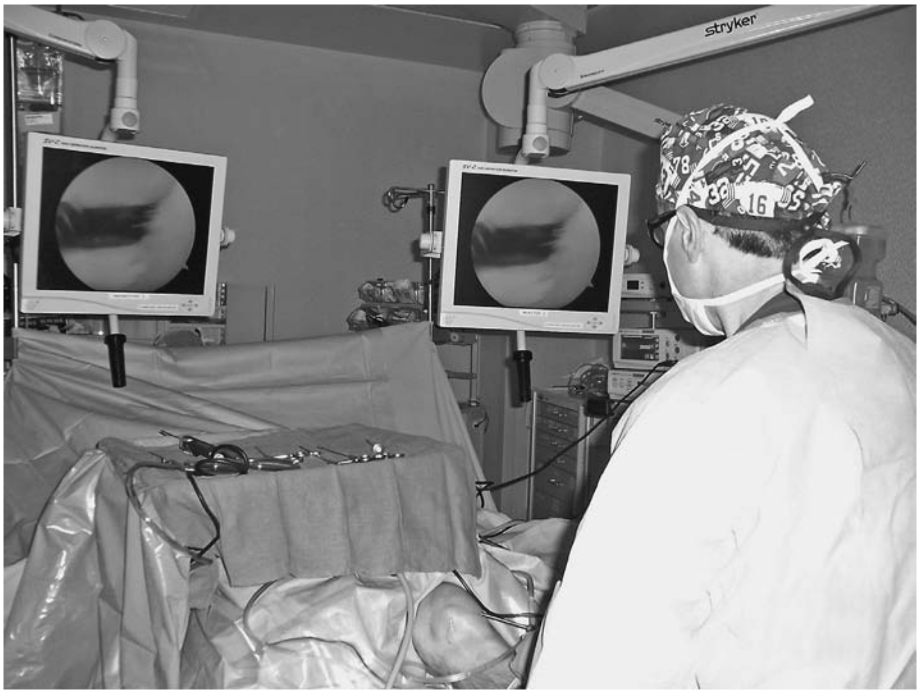
Informed Consent

Before any operation is scheduled, the surgeon must obtain informed consent from the patient. The concept of informed consent has evolved over the years and can be very different for different patients. Some patients require detailed descriptions of the operation technique, the possible complications, and the plan for rehabilitation and may want several opinions from different surgeons. Other athletes will take the opposite approach, telling the surgeon, "Doctor, I trust you, just make me better." The Internet provides an abundance of free advice, some good and some bad, regarding every type of knee injury. Using the resources of the Internet is usually helpful, but frequently, the surgeon must correct misconceptions.

Neither of these approaches is ideal. The surgeon cannot teach the patient every nuance of knee surgery, and the patient cannot be expected to become a doctor overnight. Likewise the patient who doesn't want to know any details and who leaves all decision making to the doctor is not fulfilling his or her obligations. The informed consent process is a collaboration between the surgeon and the patient where the surgeon gives the patient the information that a "reasonable" person would need to know to make a sound decision. The patient must use his or her judgment to decide whether to accept the risks of surgery in order to achieve the benefits.

Surgical Technique

These days, almost all knee surgeries are done arthroscopically or with minimally invasive techniques (see photo below). This means that visualization is done with fiberoptic telescopes connected



Typical surgical setup for arthroscopy of the knee

Source: Photo by Peter G. Gerbino, M.D.

Note: The knee is in a sterile field, all instruments are sterile, and the fiberoptic telescope is paired with a camera with the inside of the knee displayed on the monitor.

to small, high-definition video cameras through 0.25-inch (in.; 0.6 centimeter) skin incisions. Repair, removal, drilling, and sewing of tissues is also done through 0.25-in. holes. Most of these skills require a fair bit of practice, and so sports medicine physicians have to become experts at these techniques. Arthroscopic surgery has several advantages over open surgery. If the repair can be done as well with open surgery, the advantages include smaller scars, less pain, decreased risk of infection, and faster recovery. Many of the repair techniques now used can only be done arthroscopically, and surgeons are constantly finding innovative ways to improve techniques and results.

Complications

No surgeon is perfect, and no operation is perfect. The main reason to have informed consent is to make sure that the patient understands what result can be expected and what can go wrong.

Take, for example, reconstruction of the ACL. This operation can lead to many different complications. Early in the development of this operation, a patient's knees were casted for 6 weeks following surgery. This led to a condition called *arthrofibrosis,* in which excessive scar tissue forms around the kneecap, making motion more difficult.

Infections can occur following any operation, and these can have severe consequences. The patient can develop blood clots in the deep veins of the leg (deep vein thrombosis, or DVT), and these can break off, travel to the lungs, and cause death (pulmonary embolus).

Excessive bleeding into the knee following surgery can slow down rehabilitation and induce restrictive scar formation. The hardware used to secure a graft may become painful or fail. Most of these complications are very rare, but each of these and many others have occurred and will occur again. Even with a perfect knee operation, the operated knee is never as good as the original knee and will still wear out faster than the other side, leading to earlier arthritis.

Knee Surgery: Meniscus Tear

The classic meniscus tear occurs in an athlete who has a twisting knee injury under load. There is initial pain, the knee swells overnight, and there is persistent pain at the site of the torn meniscus. The athlete sees the surgeon, who suspects meniscus tear based on history and physical examination. These days, most patients would undergo MRI to confirm the diagnosis. An arthroscopic partial meniscectomy would be recommended. The factors leading the surgeon to this recommendation are as follows:

1. High activity level of the athlete
2. Pain
3. The presence of locking
4. The knowledge that few meniscus tears heal on their own
5. The understanding that left untreated, a meniscus tear can cause further joint cartilage and bone damage and lead to early arthritis

Arthroscopic surgery is used for treating a torn meniscus. This is virtually always done as an outpatient procedure, meaning that the athlete returns home the same day the operation is performed. The sequence of events begins with early arrival of the patient to the surgical center. The nurses prepare the patient for surgery, and both the surgeon and the anesthesiologist talk to the patient. In the operating room, the anesthetic is given, and the operation is done.

The surgeon examines the entire knee arthroscopically and then addresses the torn meniscus. Depending on the location of the tear in the meniscus, the pattern of the tear, and the age of the patient, the surgeon will make a decision as to whether the meniscus can be repaired. Since the meniscus only has blood supply to the outer one third, repairing the inner two thirds is unlikely to heal the tear. On the other hand, children have a better blood supply and greater healing potential, so many surgeons will repair a middle one third meniscus tear in a young person. Tears that occur longitudinally in the meniscus (either vertically or horizontally) heal better than radial tears or tears that result in a flap.

If the surgeon feels that repair is not possible, he or she uses various small instruments to remove the unstable parts of the torn meniscus. The goal is to avoid leaving tissue behind that can cause impingement leading to pain and/or further tearing.

If repair is possible, the surgeon must decide how best to stabilize the tear. Many different techniques exist for sewing a torn meniscus. Some allow complete repair by placing sutures (stitches) in the meniscus without having to make additional skin incisions. Other techniques require incisions to capture the long needles passed through the joint to the outside and for tying the sutures outside the joint. Still other techniques involve passing sutures from outside in and then tying the knots outside the joint below the skin in a small skin incision. Each technique has its pluses and minuses. No one technique is correct for every situation.

Once the repair is complete, the surgeon tests the repair with a probe and by putting the knee through a full range of motion. The small incisions are closed, and dressings are applied. Frequently, a system for providing cold therapy is used, and sometimes, a brace is used to restrict motion. Depending on the strength of the repair and the size of the tear, full weight bearing may be restricted for a period of time. If no repair has been done, the patient is allowed to bear weight as tolerated. A rehabilitation program, either self-directed or with a physical therapist, is prescribed, and the athlete follows up with the surgeon until fully healed and rehabilitated.

Knee Surgery: ACL Tear

ACL tear is another common knee injury in athletes. This large ligament in the center of the knee prevents forward motion of the tibia with respect to the femur. The ligament can tear in one of several ways. If the athlete's knee is struck from the outside (clipping-type injury), the MCL and ACL can tear. Compression on the outside part of the knee can result in lateral bone bruising and lateral meniscus tear. Another more common mechanism for ACL tear is called "indirect." This occurs when cutting or landing from a jump, and the knee gives out under the stress. The athlete hears and feels a "pop" and is unable to continue playing, and the knee swells with blood within an hour. The diagnosis is made, and an MRI scan is obtained to assess all damaged structures.

In athletes, most of the time, a torn ACL requires repair to achieve a stable knee. The original ACL tissue cannot successfully be repaired (as yet). Instead, surgeons must create a new ligament with graft material. The graft material can be the athlete's own tissue (usually a tendon from an area that can afford to lose some tissue) or can come from the tissue bank (tissue harvested from a cadaver). Other decisions include how soon to do the operation after injury, what type of fixation to use, whether to use braces, and what type of rehabilitation to follow. The surgical technique is demanding and constantly evolving, with new theories and techniques being published every year.

In the operating room, the surgeon first performs a standard knee arthroscopy, examining all aspects of the knee. If there is a torn meniscus, it is repaired or partially resected as described earlier. The torn ends of the original ACL are removed, and new holes are drilled to receive the new graft. If the patient's own tissue is being used, that material is removed and reconfigured to become a ligament. Depending on the fixation technique selected by the surgeon, sutures or other devices will be added to the tendon to allow secure fixation of the graft. If allograft (processed cadaver tissue from a tissue bank) is used, it is washed, measured, and prepared for fixation.

The graft is then passed through the tunnels in the tibia and femur, and it is locked in place on both sides with any of several metal, plastic, or absorbable devices. Critical aspects of the operation include the location of the tunnels, the tension of the graft, whether the graft rubs the femur, and whether the graft remains under uniform tension through a full range of motion.

The incisions are closed and the dressings applied. A cold therapy device is frequently used, as is a range-of-motion brace. Research has shown that using a brace after ACL surgery does not provide any additional protection from reinjury, but many patients and surgeons prefer the security a brace offers. ACL reconstruction is typically an outpatient procedure, and the patient goes home the same day.

Rehabilitation is a critical part of ACL reconstruction. It begins with early motion of the knee with or without a machine to assist with motion. Physical therapy is usually involved, and several detailed protocols exist to allow healing of tissues and restoration of strength and balance without placing excessive strain on the new ligament. Athletes are usually rehabilitated enough to return to sports in 4 to 6 months, even though the graft takes up to 3 years to become fully mature.

Knee Surgery: Patella Dislocation

Surgery for patella dislocation is standard knee arthroscopy as described earlier. If there are loose bodies (cartilage or bone fragments), they are removed. A large fragment of bone and cartilage can be replaced and held in place with screws or pins. The patella must be realigned to its track, and usually the medial patellofemoral ligament (a ligament that tethers the patella to the inside of the femur) must be repaired. Sometimes, to achieve central tracking of the patella, the outside (lateral) tissues are too tight and must be released. Rehabilitation involves protecting the repair while strengthening the knee muscles.

Knee Surgery: Patella Maltracking

One of the most common overuse injuries requiring surgery is patella overload from a patella that is tilted to the outside of the knee. This results in too much force on one part of the patella, causing pain there. If bracing and selective muscle strengthening have not succeeded in correcting the problem, the surgeon may recommend a lateral release. In this operation, a standard knee arthroscopy is performed. The tilt and lateral tracking are confirmed by direct visualization, and the tight lateral tissues are cut, allowing the patella to move medially in a more central, balanced position. Rehabilitation is similar to patella dislocation surgery, with bracing and muscle strengthening the key aspects. In the past, this operation was done excessively for many problems around the knee. Surgeons are now very careful about deciding who will benefit from this operation.

Conclusion

Knee surgery for athletic injuries is common. Most of the time, the decision-making process is based on hard facts with scientifically justified results. Arthroscopic surgery is used for most operations of the knee following athletic injury. Informed consent is necessary to ensure realistic expectations on the part of the athlete. Despite all the advances in medicine and surgery, complications will occur and are ultimately unavoidable. Surgeons, other health professionals, and athletes continuously work together to refine the decision-making process, maximize understanding, improve surgical technique, minimize complications, and optimize rehabilitation.

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See also Knee, Osteochondritis Dissecans of the; Knee Injuries; Knee Ligament Sprain, Medial and Lateral Collateral Ligaments; Meniscus Injuries; Patellofemoral Pain Syndrome

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Knee Ligament Sprain, Medial and Lateral Collateral Ligaments

The medial and lateral collateral ligaments (MCL and LCL, respectively) are two of the four main stabilizing ligaments in the knee. (The anterior and posterior cruciate ligaments [ACL and PCL, respectively] are discussed in a separate entry.) The MCL and LCL can be injured during many sporting activities, especially sports involving "cutting." Spraining these ligaments is common, and injury to the MCL is the most common ligamentous injury to the knee. Spontaneous healing with nonoperative treatment usually occurs; however, operative treatment may be beneficial if multiple ligaments of the knee are injured.

Anatomy

MCL is a complex ligamentous structure consisting of the superficial MCL and deep MCL. The superficial MCL is also called the *tibial collateral ligament*. It is the largest structure of the MCL complex. The superficial MCL attaches proximally on the medial femoral condyle and distally to the medial tibia in two places. The more proximal is 2 centimeters (cm) from the joint line, and the more distal attachment is approximately 4 to 5 cm distal to the joint line beneath the pes anserine insertion. The deep MCL is made up of medial capsular thickenings from the knee capsule. Additionally, the semimembranosus muscle gives off a tendinous expansion that is called the *posterior oblique ligament* and adds additional resistance to valgus stress when the knee is fully extended. The MCL complex's collagen fibers are arranged in parallel, giving the MCL its strength as the main medial stabilizer to resist valgus force on the knee.

The LCL is also called the *fibular collateral ligament*. It acts as the main restraint to varus stress of the knee. The LCL also helps provide additional resistance to rotation. It is part of a group of stabilizers called the *posterolateral corner ligament complex*. The LCL attaches to the femur on the lateral epicondyle and inserts onto the lateral fibular head. Additionally, there are attachments from the long head of the biceps femoris that insert onto the LCL and lateral capsular ligaments that lie deep in the LCL.

Causes

MCL injuries are caused by valgus stresses to a slightly flexed knee, such as a blow to the outside of the knee with the foot fixed. These injuries can occur in noncontact or contact sports. Noncontact maneuvers such as pivoting or cutting can result in an MCL injury. Contact injuries are usually from a lateral blow to the knee, which often occurs in football, and result in more complex injuries and complete tears.

LCL injuries are much less common and rarely occur in isolation. Most occur with injury to the posterior lateral corner ligamentous complex or the ACL or PCL. The mechanism of injury is often an anteromedial blow to the knee. Less commonly, the injury could occur from twisting or hyperextension with or without contact.

Symptoms

Athletes with MCL or LCL injuries will often complain of pain, stiffness, redness, and swelling on the medial or lateral side of the knee, respectively. The athlete will often be able to walk after injury. In more severe injuries, the athlete may complain of a feeling of instability in the knee.

Diagnosis

Physical exam starts with inspecting the knee for an effusion within the knee or swelling or redness on either side of the knee. The examiner should palpate the MCL and LCL on both the tibial and fibular attachments as well as the respective femoral condyle insertion. The range of motion (ROM), both active and passive, should be checked. The knee should then be examined using the valgus stress test at 0° and 30°. To perform the valgus stress test, the examiner should place the leg at 30° of flexion. One of the examiner's hands should then be placed on the lateral side of the femoral condyle, with the other hand grasping the athlete's ankle medially and holding it in neutral position. A valgus stress is then placed on the knee, and the amount of joint line opening is assessed. The same maneuver is repeated at 0° of flexion. Likewise, the LCL should be assessed with the varus stress test at 0° and 30°. This is performed with the examiner placing the leg over the side of the table, placing one hand on the medial femoral condyle and the other hand on the lateral ankle, holding it in neutral position. A varus stress is then placed on the knee, and the size of the joint line opening assessed. The noninjured knee should also be examined to compare the injured side with the noninjured side. The American Medical Association's guidelines for grading an MCL or LCL injury are as follows:

Grade I: 0 to 5 millimeters (mm) of joint line opening

Grade II: 5 to 10 mm of joint line opening

Grade III:>10 mm opening, with no firm end point

Grades I and II are sprains and partial tears, whereas Grade III injuries are complete tears. A complete physical exam of the knee and leg should be done to assess for additional ligamentous injury. Additional tests including the Lachman test, anterior and posterior drawer test, pivot-shift test, and dial test are to be performed and are described elsewhere in this encyclopedia. A neurovascular exam, including motor sensation and palpating the popliteal, dorsalis pedis, and posterior tibial pulse, must be completed.

After the physical exam, plain radiographs should be ordered, including anteroposterior, lateral, 45° postero-anterior, and sunrise views. Varus and valgus stress radiographs may yield additional information. Additionally, magnetic resonance imaging (MRI) without contrast medium may be useful as it is highly sensitive in detecting tears of the collateral ligaments as well as other pathology.

Treatment

Nonsurgical Treatment

Medial Collateral Ligament

Isolated Grade I or Grade II injuries are treated nonoperatively. Ice, elevation, and compression are necessary. The patient may continue weight bearing as tolerated. Initially, the athlete may require the use of crutches. Nonsteroidal anti-inflammatory drugs often help decrease inflammation, pain, and swelling. Hinge knee bracing may be used. Early ROM is encouraged. Physical therapy for quadriceps strengthening and closed-chain exercises should be performed. The goal for recovery is full ROM, adequate strength, and no laxity within 4 to 6 weeks.

Isolated Grade III injuries are also initially treated nonoperatively. Ice, elevation, and compression are again necessary. Initially, the patient should be non–weight bearing and should wear a hinged knee brace for support. Early ROM and physical therapy are also initiated. Examination of the knee throughout the rehab process is imperative. At 4 weeks after the injury, if valgus stress testing is improved to Grade I or less, full weight bearing may commence. The athlete may be allowed to return to activities when full ROM, adequate strength, and Grade I or less laxity is achieved. Grade III injuries may take up to 8 to 12 weeks to heal.

Lateral Collateral Ligament

LCL injuries often heal more slowly than MCL injuries. Grade I and II injuries are treated conservatively. Ice, elevation, compression, and nonsteroidal anti-inflammatory drugs are the mainstay of therapy. The athlete should be placed in a hinged knee brace and should continue weight bearing as tolerated for 4 to 6 weeks. Early ROM is encouraged. Physical therapy for quadriceps strengthening and closed-chain exercises should be performed. The goal for recovery is full ROM, adequate strength, and no laxity within 6 weeks.

Grade III injuries often do poorly with conservative therapy due to rotational instability with posterolateral corner ligamentous injury.

Surgery

Surgery on either the MCL or the LCL is reserved for athletes who have symptomatic Grade II or Grade III instability after completion of a functional rehabilitation program or knees with multiple ligaments injured and recurrent instability. The goals of surgery include restoring normal stability and ROM.

Medial Collateral Ligament

Repair of the MCL is possible when the tear is at the bone-ligament junction. The ligament can be anchored to the bone with suture anchors. Additionally, this can be reinforced with a semitendinosus graft. If the tear is in the middle of the ligament, reconstruction can be performed with gracilis or semitendinosus autograft or Achilles tendon allograft. Additional tightening of the deep MCL and posterior oblique ligament can help reinforce the reconstruction.

Lateral Collateral Ligament

Early repair within the first 1 to 2 weeks after injury has better outcomes. Suture anchors, direct suture repair, recess procedures, and autograft or allograft reconstructions are all possible surgical options for LCL repair and posterolateral corner reconstruction.

After Surgery

Medial Collateral Ligament

Apart from ice, elevation, and compression, rehab protocols vary. Most would initially immobilize the knee in a hinged knee brace locked in extension for 4 weeks. During these 4 weeks, the athlete can perform quad sets and patellar mobilization, and continuous passive ROM from 0° to 45° can be initiated. Without active ROM, the patient can do weight bearing as tolerated with a hinged knee brace locked in extension. From 2 to 4 weeks, the patient can begin active assisted ROM from 0° to 60°. At 4 weeks, active assisted ROM from 0° to 90° may be completed, and the brace may be opened. At 6 weeks, active ROM may begin from 0° to 100° in the hinged knee brace. The brace may be removed around Week 8, and rehab should be continued with the goal of return to sports in 10 to 12 weeks.

Lateral Collateral Ligament

Ice and elevation with non–weight-bearing restrictions in a knee immobilizer in full extension are the mode of treatment in the first 6 weeks. During this time, passive ROM, quadriceps sets, and straight leg raises in the knee immobilizer are performed. After 6 weeks, the knee immobilizer is discontinued, and weight bearing as tolerated is begun. Stationary biking with low resistance is initiated at 6 weeks. It may take up to 4 months to return to the previous level of activity.

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See also Knee Injuries; Knee Injuries, Surgery for; PRICE/MICE

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Knee Plica

Knee plica syndrome, or synovial plica syndrome, is among the common knee injuries that occur in athletes. *Plica syndrome* refers to the injury or irritation of the synovial plica folds in the knee, followed by severe pain in the joint. Although the condition does not damage the knee (rarely, a large plica can rub on the articular cartilage and cause wear), it can be very painful. Diagnosing plica syndrome can be challenging, but treatment is simple.

Following a description of the anatomy of the knee, this entry discusses the signs, symptoms, causes, and treatment of knee plica syndrome.

Anatomy of the Knee Joint

The knee joint is the most complex joint of the entire body, formed by the condyles at the distal ends of the femur and the condyles at the proximal end of the tibia. It is a synovial joint of the hinge variety, the articular surfaces being the two femoral condyles, the adjacent surfaces of the superior aspect of the tibial condyles. The ends of the femur and tibia are covered with cartilage that resembles the shiny smooth white end of a chicken bone. The cartilage provides a smooth low-friction surface for the knee to allow movement. The bone directly underneath the cartilage is called the *subchondral bone*. The purpose of the subchondral bone is to support the cartilage during weight-bearing activities. The articular surfaces between the femur and the patella are the V-shaped trench on the anterior surface of the femur at its lower end and the adjacent surfaces on the posterior aspect of the patella, or kneecap. The joint is lined by the synovial membrane, which extends from one articular surface to the other. Also referred to as *synovium*, the synovial membrane secretes a clear fluid called the *synovial fluid*, which lubricates the joint, thus helping bones move easily during joint movements. Other structures that help in reducing friction between the bones and the muscle tendons are the synovial bursae and the *plicae,* folds of the synovial lining of the knee joint capsule.

The ligaments of the knee joint that provide stability are the collateral ligaments, the cruciate ligaments, the oblique popliteal ligament, and the patellar ligament. The joint is made stable by the tone of the quadriceps femoris muscle.

Synovial Plicae

As noted, plicae are extra folds in the synovium; they are the remnants of the mesenchymal tissue and septa, which are formed during the embryonic development of the knee joint. There may be several of these folds in the normal knee. Commonly, there are four such plicae in the knee; these are normally small and smooth, but once injured or irritated, they may become thick, causing pain. Among the four plicae, the one on the inner side, called the *medial plica*, is more prone to injuries, running from the lower end of the kneecap to the lower end of the femur.

Causes

Normally, plicae are small and smooth and may be present for years without producing symptoms until they get inflamed or irritated, most commonly through either overuse or direct traumatic injury.

Plica pain can occur either suddenly (acute) or over a long period (chronic).

Acute Plica Pain

A sudden injury to the knee, either by a fall or due to the knee getting badly hit by an object, causes the medial plica to respond by becoming irritated and thick. The thickened area thus begins to catch on the femur as the knee moves.

Chronic Plica Pain

Chronic plica problems develop when the plicae get irritated by exercise, repetitive motion, or kneeling. Activities that involve repeated bending and straightening of the knee, such as running, biking, or use of the stair climber, can irritate the plicae and cause pain.

Signs and Symptoms

The most common signs and symptoms in a patient with painful knee plicae are as follows:

1. A patient with knee plica syndrome usually arrives with a history of knee pain in the front or just on the inner side of the knee. Extensive bending of the knee aggravates the pain.
2. Localized swelling is observed in rare cases where the plicae have been severely irritated.
3. There may also be a clicking or snapping sensation along the inside of the knee as it is bent.
4. Patients often experience knee locking, a condition in which the knee can be flexed but cannot be extended fully.
5. Knee weakness often occurs when knee plica is left untreated for a very long time.
6. The area around the knee is also tender to the touch, and a thickened, cordlike structure can usually be felt.

Diagnosis

Medical History

The patient provides details about symptoms and describes any injury, condition, or general health problem that might be causing the pain.

Physical Examination

The clinician bends, straightens, rotates (turns), or presses on the knee to feel for injury and discover the limits of movement and the location of the pain. The patient may be asked to stand, walk, or squat to help the clinician assess the knee's function.

Diagnostic Tests

As knee plica syndrome is difficult to diagnose, other common knee injuries must first be eliminated from consideration. Imaging techniques including X-ray (radiography), computerized axial tomography (CAT), and magnetic resonance imaging (MRI) may be performed to rule out the possibility of any fracture, soft tissue injury, or meniscus tear. The clinician then performs simple tests such as the Stutter test and Hughston plica test.

Stutter Test

The patient is seated with his or her knee flexed over the edge of the table; the examiner stands lateral to the involved side, and lightly cupping one hand over the patella, the examiner has the patient slowly extend his or her knee. The test is positive when there is irregular patellar motion/stuttering between 40° and 60°. A positive test indicates symptomatic medial synovial plica.

Hughston Plica Test

The patient is supine with his or her knee flexed to 90°. The examiner internally rotates the tibia and passively moves the patella medially while palpating the anteromedial capsule. The examiner flexes and extends the knee from 90° to 0° while the tibia is internally rotated. The test is positive when there is pain and/or palpable clicking. A positive test indicates symptomatic medial synovial plica.

Arthroscopy

To confirm knee plica syndrome, arthroscopy is performed. A lighted optic tube (arthroscope) is inserted into the joint through a small incision in the knee, and images of the inside of the knee joint are viewed on a video screen.

Treatment

Nonsurgical

The majority of people with knee plica syndrome will get better without surgery. The treatment is directed along a three-phase protocol: (1) control of pain and inflammation, (2) restoration of function, and (3) return to sports.

Inflammation can be reduced in the following ways:

- Administer nonsteroidal anti-inflammatory medications such as ibuprofen, indomethacin, naproxen, oxaprozin, and celecoxib.
- Reduce activity such as running, biking, or using a stair climber.
- Apply ice to reduce swelling in the area of the plica. Rub ice for 3 to 5 minutes around the sore area until it feels numb.
- A cortisone injection into the plica, or simply into the knee joint, may quickly help reduce the inflammation around the plica. Cortisone is a powerful anti-inflammatory medication.
- Ultrasound and friction massage may be used to reduce inflammation in the plica.
- To reduce the inflammation, modalities such as *iontophoresis* (using low-intensity electric current to transport medications through the skin) and *phonophoresis* (using ultrasound to transport medications through the skin) are employed.

Rehabilitative Exercises

Once the inflammation has been controlled and pain levels begin to fall, rehabilitative exercises should be started. The goal is to increase overall quadriceps, hamstring, and calf strength, as well as increasing the overall flexibility of muscle. Examples of such exercises include painfree squats that progress to one-leg squats, side step-ups, closed-chain terminal knee extension, and applicable sport-specific exercises. However, care should be taken to avoid deep squats as they can increase the pain. These exercises should be performed using progressive resistance exercise (PRE) principles, gradually increasing load and intensity as the pain and inflammation allow.

Surgical Treatment

If treatment fails to relieve symptoms within 3 months, the clinician may recommend arthroscopic surgery to remove the offending plica. Once the plica is located with the arthroscope, small instruments are inserted through another incision to cut away the plica tissue and remove the structure. Rehabilitation sessions after surgery are designed to ease pain and swelling and help the athlete begin gentle knee motion and thigh-tightening exercises. Patients rarely need to use crutches after this kind of surgery.

Prevention

Warm-up and stretching before exercising or participating in sports activities is strongly recommended. Stretching the quadriceps and hamstrings reduces tension on the tendons and may reduce irritation of the knee during activity. For patients who are prone to irritation of the plica, activities that repeatedly bend and straighten the knee, such as biking or use of a stair stepper machine, should be avoided until they consult their physician.

Reem Shahid and Madeeha Khalid

See also Knee Injuries; Knee Injuries, Surgery for; Principles of Rehabilitation and Physical Therapy; Stretching and Warming Up

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Kneecap, Subluxating

The *patella*, commonly called the kneecap, may become partially or completely dislodged from its normal position. Partial dislodgement is termed *subluxation,* and complete dislodgement is termed *dislocation*. The spectrum of dysfunction between subluxation and dislocation is referred to as *patellar instability*. The first time a dislocation occurs, an acute dislocation is diagnosed. Repeated dislocations or subluxations are known as *recurrent* or *chronic instability*. Acute patellar dislocation is the most common knee injury in children and adolescents.

Anatomy

Muscles are connected to bones via thick tissues known as *tendons*. The tendon of the quadriceps muscle attaches to the patella on its upper or superior end. The patellar tendon connects the patella to the lower leg by attaching to a specific part of the shin termed the *tibial tubercle*.

As the knee bends or flexes from a straight (extended) position, the patella engages and becomes constrained within a contoured portion of the end of the thighbone, known as the *femoral trochlea*. Stability of the patella within the trochlea depends on several soft tissue structures with specific names. These stabilizing structures may be thought of as biological "brakes."

In the early stages of flexion, before the patella engages within the trochlea, the position of the patella is primarily stabilized by a band of tissue known as the *medial patellofemoral ligament*. This ligament runs from the side of the patella to a portion of bone on the side of the femur. Once the patella becomes engaged within the trochlea, the primary restraint to subluxation of the patella is the complementary geometry of the patella and the trochlea. Other sources of stability to the normal position of the patella are the quadriceps and patellar tendons and the bottom or inferior aspect of the quadriceps muscle known as the *vastus medialis obliquus*.

Causes

Patellar dislocation or subluxation may occur with or without preceding injury. Instability without prior trauma occurs in patients with underlying abnormalities of the normal anatomy. These abnormalities include an abnormal shape of the trochlea (known as *trochlear dysplasia*) and malalignment of the legs, which places excess stress on the patella as the knee moves through flexion and extension. Knock-knees, or genu valgum, is one type of malalignment that can place excess stress on the patella. Rotational malalignment, in which the thighbone causes the patella to point inward (increased femoral anteversion) in combination with a tibial tubercle that is pointed outward (external tibial torsion), is another type of abnormality that can place excess stress on the patella. During growth and development, the amount of genu valgum and rotational malalignment may be decreased, as in teenagers. Other abnormalities that can cause patellar instability include loose joints (ligamentous laxity) with a hypermobile patella that is located higher in relation to the end of the thighbone than normal (patella alta). Certain medical conditions, such as Down syndrome, are associated with loose joints.

Traumatic dislocation may occur following a fall, twisting injury, or direct blow to the knee. The anatomy of the knee may be normal prior to the injury, but some underlying pathology is often present. With the dislocation, there can be damage to the knee, including rupture of the medial patellofemoral ligament. In addition, bone and cartilage can be injured. A piece of bone and cartilage can break off, causing a "loose body."

Symptoms

Patellar dislocation most commonly results in the patella being moved to the outside of the knee, a lateral dislocation, and the bony prominence is noted on the lateral side of the knee. The patella will often return to its normal position shortly after the dislocation occurs and the bony prominence disappears.

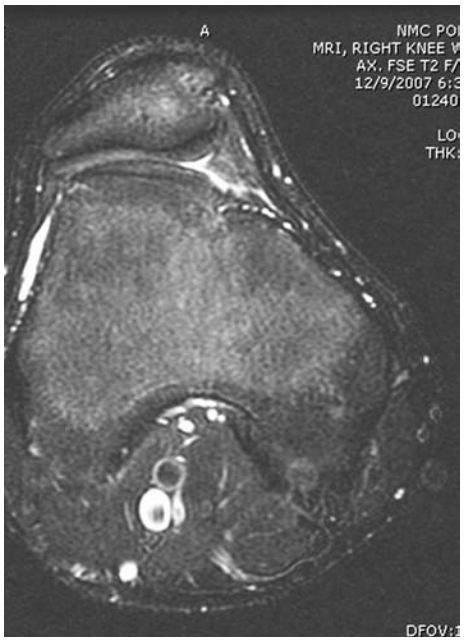
Patellar subluxation may cause pain as the patella moves to the outer edge of its normal position.

Diagnosis

Patellar dislocation may be diagnosed by examining the patient and noting the absence of the patella from its normal central position and the laterally located bony prominence. Radiographs (X-rays) are not necessary to diagnose the dislocation. However, certain X-rays will help identify the condition. The Merchant view radiograph will reveal that the patella has been moved out of the trochlea.

Patellar subluxation may also be demonstrated by following the position of the patella as the knee is moved through flexion and extension. The examiner may also attempt to judge how much the patella can move laterally. This is known as the *apprehension test*, as the patient may experience apprehension if he or she feels like the kneecap is about to dislocate.

Further examination and radiographs can help determine the cause of the patellar instability. Patients are checked for signs of ligamentous laxity and hypermobile patellae. The alignment and rotation of the legs are checked for knock-knees or increased femoral anteversion in combination with external tibial torsion. Radiographs of the knee, including anteroposterior, lateral, and Merchant views, are obtained. The lateral view will demonstrate patella alta (previously described) when present. The Merchant view will demonstrate abnormal tilt or position of the patella within the trochlea.



Magnetic resonance imaging (MRI) demonstrating tilted and subluxated patella (*top*)

Source: Eric Shirley, M.D.

Treatment

Both nonoperative and operative treatment options are available for patients with patellar instability. Physicians will individualize treatment based on a number of factors. These include the types of sports/activities played by the patient, the age of the patient, the severity of injury, the number of dislocations, and other injuries present.

First-Time Dislocation

The initial action after the first dislocation occurs is to verify that the patella has been reduced, or returned to its normal position. If the patella has not reduced on its own, this must be done by the medical provider. Reduction is facilitated by placing the patient on his or her belly (prone position), extending the hip, and then gradually extending the knee. Rarely, a patient must go to the operating room to reduce the patella.

Once the patella is reduced, it is then determined if surgery is necessary. Surgery is needed after a first dislocation if a portion of cartilage from the femur or patella was dislodged, resulting in a loose body. A loose body may be visualized on X-ray or a magnetic resonance imaging (MRI) scan (see image, left). If a loose body is present, arthroscopic surgery is performed to remove the loose body and address the cartilage damage. In addition, the underlying cause of the dislocation may be addressed at that time.

More commonly, a loose body is not present, and nonoperative treatment is begun. Nonoperative treatment consists of immobilizing the knee in a brace and then starting range-of-motion exercises and muscle strengthening with balance training. Some surgeons consider repairing the medial patellofemoral ligament after the first dislocation. However, success can occur with nonoperative treatment if loose bodies are not present within the knee.

Chronic Instability

Chronic instability can result in cartilage damage as repeated dislocations occur. Physical therapy is used to strengthen the vastus medialis obliquus muscle in order to decrease the risk of recurrence. Patellar-stabilizing braces or special taping can be used to provide additional support. Activities may be modified to avoid sports that place the patella at risk for dislocation. If repeated dislocations occur, surgery is indicated more by patient preference to eliminate recurrence than by a certain number of episodes.

Surgical treatment is directed at the underlying anatomical abnormalities that are resulting in instability. If the alignment of the legs is normal, soft tissue procedures such as lateral release and medial imbrication are performed. The lateral release reduces tension on structures that are causing the patella to be tilted, while the medial imbrication tightens tissues on the medial side of the knee that have been stretched. This procedure can be performed open with larger incisions or via arthroscopy. Another soft tissue procedure that can be performed is reconstruction of the medial patellofemoral ligament using a hamstring tendon or a donor/cadaver tendon.

Procedures that cut and realign the bones are performed when malalignment is present. The procedure that cuts the bone and moves the position of the patellar tendon is known as a *tibial tubercle osteotomy*. This procedure requires the patient to be skeletally mature so that the growth plate of the bone (physis) is not damaged. In younger patients with malalignment, procedures that redirect the patellar tendon by moving a portion of the tendon itself or by attaching a hamstring to the patella can be performed. At the time of surgery, the knee is inspected via arthroscopy for other injuries, as cartilage or meniscus injuries may be present as well.

After Surgery

Treatment protocols following surgery vary depending on which procedure was necessary to address the underlying anatomical abnormalities. Typically, the knee is moved early to prevent stiffness. Recovery is often faster after soft tissue procedures than following osteotomies. Return to sports is feasible when quadriceps strength, balance, and endurance have been achieved. Usually, sport-specific drills are begun first.

Eric Shirley

See also Patellar Dislocation; Patellar Tendinitis; Patellofemoral Pain Syndrome

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KNOCK-KNEES (GENU VALGUM)

Genu valgum (knock-knees) is an angular deformity of the knees. Young children and youthful athletes are often evaluated for this condition, but most patients are found to be within normal limits. Most cases of knock-knees will resolve on their own. It is important to identify patients outside the normal limits who need further evaluation and to give families reassurance about those patients who are within normal limits.

Normal Development of the Legs

While developing, the fetus is usually positioned with hips and knees flexed in the uterus. The feet and tibia can be internally rotated (pointed in). This positioning causes a tightening of the medial ligaments of the knee, leading to genu varum (bowlegs) at birth. The bowlegged position at birth is normally the maximum for the patient.

As the child begins to walk and grow, the tightened ligaments begin to stretch, allowing the knees to straighten out. Between 18 and 22 months, the angular deformity begins to correct, and the legs will appear straight.

This straightening will continue over the next 3 years and actually lead to an overcorrection, causing genu valgum (knock-knees). This is usually most evident at about 4 years of age. As the child continues to age and grow, the genu valgum begins to correct. By about 7 years of age and into adulthood, most people will retain a slight valgus deformity of about 5° to 8°.

Clinical Evaluation

History

One of the most important things to consider is the patient's age. Genu valgum occurs most commonly between 3 and 4 years. It is common in obese girls as well. It is important to identify whether the deformity is worsening. If possible, it can be helpful to review old photographs of the child's legs. Pain is an uncommon complaint.

Dietary history can reveal important information that may lead to nutritional deficiency. Family history and past medical history should also be reviewed. A history of fracture of the tibia can lead to knock-knees during the following 12 to 18 months.

Physical Exam

Physical exam should begin with plotting overall height, as short stature is common in patients with rickets and skeletal dysplasia.

With the patella facing forward, the clinician measures the angle of the knee. Measuring the intercondylar distance (between the two medial femoral condyles) and intermalleolar distance (between the two medial malleoli) can provide objective information to assess the deformity. There are charts available for plotting these measurements to help identify normal versus abnormal angular deformities.

Intercondylar measurement with genu varum

Source: Kevin D. Walter, M.D. Photo courtesy of Children's Hospital of Wisconsin.

Intermalleolar measurement with genu valgum

Source: Kevin D. Walter, M.D. Photo courtesy of Children's Hospital of Wisconsin.

The child may need to return every 3 to 6 months for repeat measurements to ensure that the deformity is not worsening. It is important to take the measurements in the same fashion (lying down or standing) each time for consistency.

Radiographs

Ideally, X-rays should be done in the standing position with kneecaps facing forward. X-rays should include the hips to the ankles.

Diagnosis and Treatment

Observation and reassurance are the hallmarks of treatment of genu valgum. However, if there is pain or loss of function, surgery should be considered. Also, many patients will want surgery for strictly cosmetic purposes.

Physiologic Knock-Knees

This is symmetric and occurs usually between the ages of 2 and 6. Parents may report improvement in the deformity. The family history is negative. The patient should have a normal height and normal screening measurements. The family should be reassured, and the measurements should be followed every 3 to 6 months if needed.

Posttraumatic Genu Valgum

This results from an overgrowth of the tibia about 12 to 18 months after a fracture of the proximal tibia. This complication may be unavoidable, even with proper treatment of tibia fractures. Over the following years, there may be a slow reduction in deformity.

Treatment of posttraumatic genu valgum begins with proper management of proximal tibial fractures by ensuring proper alignment and immobilization. The family will need to be reassured that this will not damage the joint and will decrease in time. If it persists, there is a role for operative intervention by an orthopedic surgeon. The procedure involves an osteotomy or a hemiepiphysiodesis.

Rickets

Nutritional deficiencies (lack of calcium, lack of vitamin D, or malnutrition) and vitamin D resistance (hypophosphatemic) can lead to rickets. Rickets is associated with both genu valgum and genu varum. Children with rickets usually have short stature and a family history of angular deformities. X-rays will show poor calcification in the bones (osteopenia) and wide physis of the joints (wide bones in the joints). There may also be bowing of the tibia and femur. Labs reveal low calcium and phosphorous.

Rickets is primarily treated by an endocrinologist to help medically manage the patient. By correcting the diet and returning the patient to his or her normal metabolic state, the deformity will usually correct. If it does not, then the orthopedic surgeon may consider bracing or surgery, such as an osteotomy or stapling. It is important to ensure that medical therapy is maximized before attempting surgical intervention.

Other Causes

There are less common causes of angular deformity. These include metabolic disorders, chronic infections due to tuberculosis, and fibrous dysplasia. These issues are best managed by a medical team of specialists.

Kevin D. Walter

See also Bowlegs (Genu Varum); Calcium in the Athlete's Diet; Dietary Supplements and Vitamins; Dietitian/Sports Nutritionist

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Krebs Cycle and Glycolysis

Living cells require an energy resource to function. In the human body, this "energy currency" is adenosine triphosphate (ATP). ATP is used by cells to grow, to reproduce, and to respond to the stresses and strains of life, including exercise and muscle contraction.

ATP is a molecule that is made of the nuceloside *adenosine* and three (tri) inorganic phosphate groups. When water is added to ATP, one phosphate group breaks off and releases energy. This leaves adenosine with two phosphate groups, becoming adenosine diphosphate (ADP).

In cells, ATP is stored in very small quantities, which would sustain exercise only for a few seconds. Therefore, the cells in muscles must keep making new ATP to keep the muscles exercising for longer durations.

To make new ATP, chemical reactions occur, adding a phosphate group back to ADP to create a new ATP molecule. If this process is done in the presence of oxygen, it is called *aerobic metabolism* or oxidative phosphorylation, and if no oxygen is present, it is called *anaerobic metabolism*.

The most common and easily accessible way for the body to make ATP is through the breakdown of glucose. The foods that we eat contain carbohydrates, which are taken up by the cells and stored in the muscles and liver as a compound called glycogen. When needed, glycogen can be broken down into individual molecules of glucose. This process is called *glycogenolysis* (the breakdown [lysis] of glycogen). Once glucose is available, three processes can occur in the cell to make ATP: (1) glycolysis, (2) the Krebs cycle, and (3) the electron transport chain.

Glycolysis

Glycolysis is a metabolic process that begins with one molecule of glucose and ends with two molecules of pyruvate. In the process, a net of two molecules of ATP are produced.

The 10 steps of glycolysis are diagrammed in Figure 1.

Once pyruvate is created from glycolysis, it has two potential fates. What the pyruvate becomes next depends on whether or not there is oxygen available in the cell.

If oxygen is not present (anaerobic metabolism), then the pyruvate is converted to lactic acid. Lactic acid can accumulate and is thought to cause muscle fatigue and soreness. This occurs during exercise involving explosive, fast movements, such as weight lifting or sprinting. Since lactic acid cannot be further broken down for ATP production, the two molecules of ATP from glycolysis are all that can be produced from this type of metabolism. If, however, oxygen is available (aerobic metabolism), then the pyruvate is made into another compound called acetyl-CoA (coenzyme A) and enters the Krebs cycle to produce more ATP. This aerobic metabolism occurs during mild, moderate, and longer-duration exercises such as walking, jogging, or biking.

Krebs Cycle

The *Krebs cycle*, also known as the tricarboxylic acid (TCA) or citric acid cycle, is a series of reactions that continue the breakdown of glucose from glycolysis.

The eight steps of the Krebs cycle are diagrammed in Figure 2.

The Krebs cycle occurs in the mitochondria (the powerhouse of the cell) and ultimately produces both ATP and hydrogen ions. The hydrogen ions (which are transported by the enzymes NAD [nicotinamide adenine dinucleotide] and FAD [flavin adenine dinucleotide]) are used in the electron transport chain to make even more ATP.

Electron Transport Chain

The electron transport chain is the final phase of energy production in the cell and occurs across the membrane of the mitochondria. This pathway takes the hydrogen ions created in the Krebs cycle and uses them to pass electrons down an energy chain to form a proton gradient. This gradient powers ATP synthase at the end of the electron transport chain to produce ATP.

Altogether, during aerobic metabolism, 1 molecule of glucose is able to produce up to 38 molecules of ATP. This is the reason why muscles are able to make enough ATP for long periods of mild to moderate exercise.

Other Energy Sources

If all the glucose is used up and no dietary carbohydrate is available (which can occur during prolonged

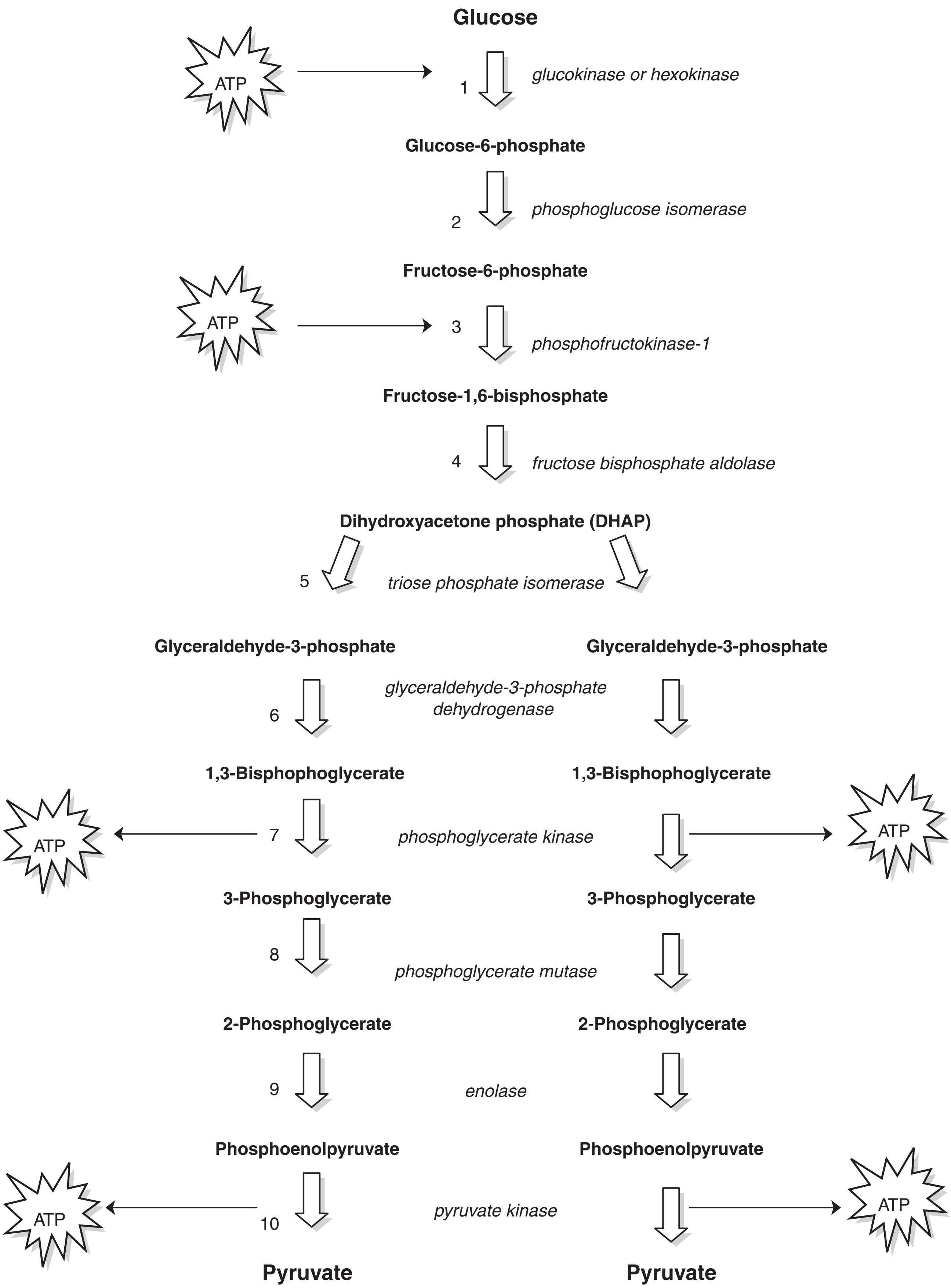

Figure 1 Glycolysis

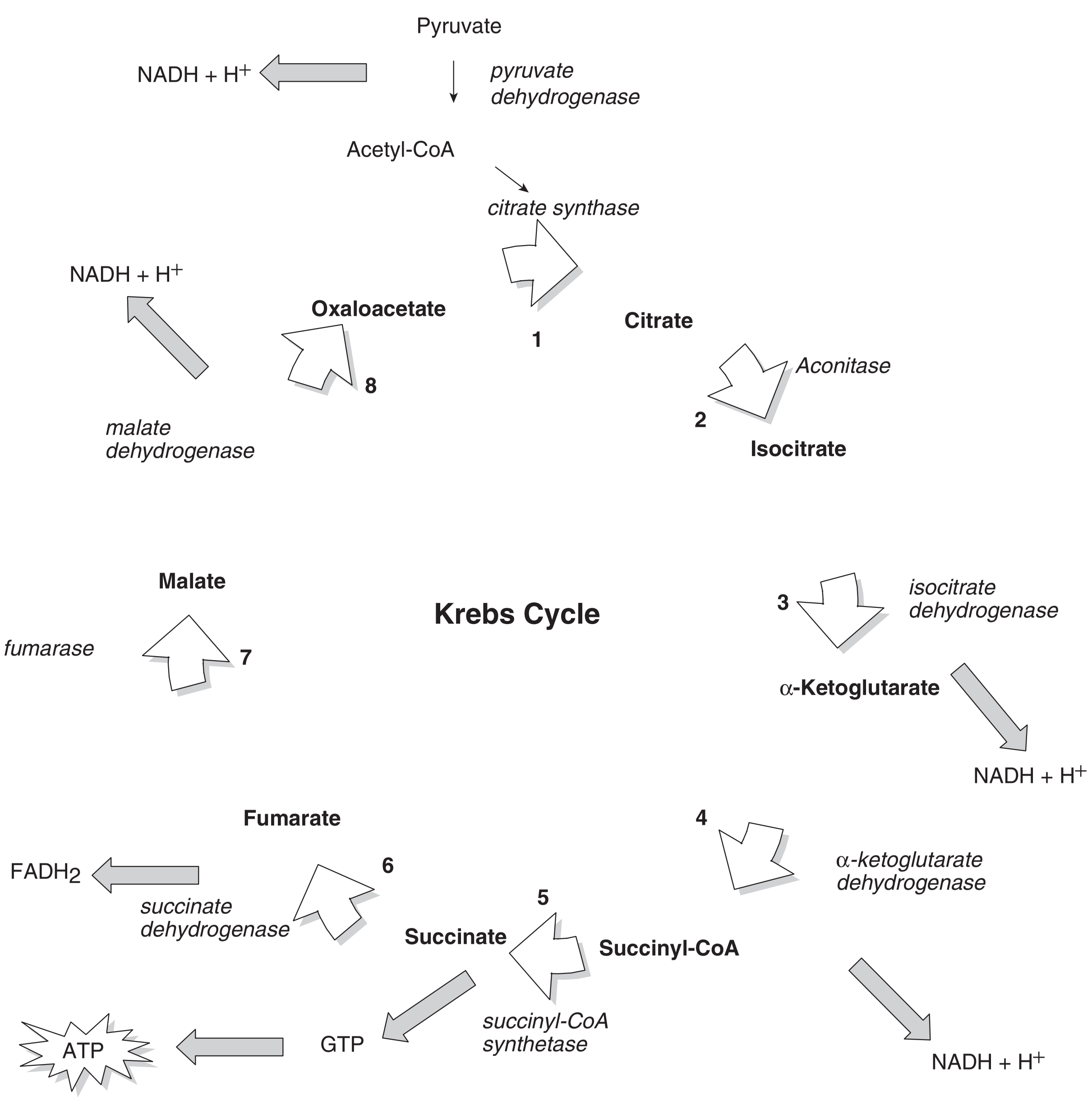

Figure 2 Krebs Cycle

periods of exercise), the body will then rely on other sources of fuel to be converted to glucose and/or acetyl-CoA directly to continue the activity. Dietary fat requires lipolysis and β-oxidation to become acetyl-CoA. Protein requires breakdown into amino acids that can be metabolized to glucose or directly to acetyl-CoA. If dietary glucose, fat, and protein are not available and the glucose stores are used up, the body will resort to using fatty acids and amino acids from the blood and tissues to eventually produce ATP.

Summary

In summary, muscle cells need energy to perform any type of exercise. Anaerobic exercise, such as weight lifting and sprinting, uses the small amount of ATP made through glycolysis. Aerobic exercise, such as light to moderate jogging and biking, uses the much larger amount of ATP made from the combination of glycolysis, the Krebs cycle, and the electron transport chain. These three processes enable cells to have a constant supply of ATP for exercise. If glucose is depleted and oral carbohydrates are not available, these three functions still occur, but less efficiently, as they use the available fatty and amino acid sources.

Leah Jacoby and Kathryn E. Ackerman

See also Calcium in the Athlete's Diet; Carbohydrates in the Athlete's Diet; Dietary Supplements and Vitamins; Dietitian/Sports Nutritionist; Fat in the Athlete's Diet; Nutrition and Hydration; Postgame Meal; Pregame Meal; Protein in the Athlete's Diet; Salt in the Athlete's Diet; Sports Drinks

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Leadership in Sports

Leadership refers to the behavioral process of influencing individuals and teams toward the attainment of specific goals. In sports, leadership roles can be prescribed as part of a formal role (e.g., manager, coach, team captain), or it can emerge as part of an informal role (e.g., peer leader, mentor). In the field of sport psychology, considerable attention has centered on the leadership behaviors used by coaches. In particular, research has sought to understand how these behaviors can result in or impair coaching effectiveness.

The multidimensional model of leadership, developed by Packianathan Chelladurai, represents one of the most extensively applied approaches to the study of leadership in sports. Chelladurai proposed that effective leadership is dynamic and based on a complex series of interactions between the coach, his or her athletes, and situational constraints. Specifically, Chelladurai recognized that the leadership behaviors of a coach are influenced by the personal characteristics of the coach (e.g., the experience of the coach), the characteristics of the situation or context in which the coaching takes place (e.g., the competitive level), as well as the personal characteristics of the athletes being coached (e.g., the age of the athletes). Of particular note, Chelladurai proposed that coaches will be most effective, and athletes most satisfied, when there is a direct congruence between a coach's *actual* behaviors, those behaviors *preferred* by his or her athletes, and the behaviors identified by the situation as being *required* for the athletes to perform successfully.

A recent example from the field of professional (American) football aptly describes the importance of ensuring that the actual, preferred, and required behaviors of coaches are directly aligned. After a disappointing season in 2006, Tom Coughlin, head coach of the New York Giants, became the focus of much media scrutiny as reports of player discontent and team disharmony abounded. He was considered by many observers to be an autocratic coach with an explosive temper. However, in the buildup to and during the 2007 season, Coughlin markedly adjusted his leadership style. He sat down to talk with his players to find out what they were thinking and opened up channels of communication. The previously stern coach went bowling with his players to establish rapport, and he empowered the players by involving them in the decision-making processes of the team. This approach appeared to be effective, as the New York Giants went on to defeat the heavily favored, and previously undefeated, New England Patriots at Superbowl XLII. Although several factors invariably go into determining team success, what this example clearly illustrates is that coaches can work at, and improve, their coaching behaviors to meet the needs of their team. To quote the well-known American football coach Vince Lombardi, "Leaders are made, they are not born; and they are made just like anything else, through hard work."

Relationship Quality

From a relationship-oriented perspective, the British-based psychologist Sophia Jowett has emphasized that for coaches to develop effective and mutually beneficial relationships with their athletes, three distinct relational needs require attention. The first of these, termed *closeness,* refers to the affective ties between the coach and the athlete, and it reflects the degree to which athletes and coaches like, respect, and trust one another. Second, Jowett proposed that for relationships to function effectively, both the coach and the athlete must report positive intentions to remain in the partnership. This reflects a high degree of *commitment* between the coach and the athlete. Finally, the extent to which the coach and the athlete work together to attempt to improve performance, through inclusive, responsive, and reciprocal behaviors (*complementarity*), also forms a central component of the coach–athlete relationship. A growing body of evidence has provided support for Jowett's framework, whereby the extent to which coaches and athletes report closeness, commitment, and complementarity has been found to predict outcomes such as relationship longevity and sustained athlete performance.

Coaching Efficacy

Beyond relationship quality, sport psychology researchers have also been particularly interested in understanding the extent to which the various psychological characteristics of the coach relate to athlete development. One such psychological characteristic that has received considerable attention relates to the effects of coaches' *efficacy beliefs*. Coaching efficacy corresponds to the extent to which coaches are confident in their abilities to influence the learning, development, and performance of their athletes. Deborah Feltz and her colleagues have developed a multidimensional model of coaching efficacy that has been used in numerous observational as well as intervention-based studies. In this model, Feltz suggested that coaches can display confidence in relation to different aspects of their trade, including confidence in their abilities to (a) coach during competition and lead their team to successful performance (game strategy efficacy), (b) mold the psychological skills and states of their athletes (motivation efficacy), (c) teach sport-specific skills (technique efficacy), and (d) influence the personal development of their athletes (character-building efficacy). In general, when coaches are confident in their own capabilities, they tend to make use of more positive instructional behaviors, resulting in their athletes being more satisfied with them, and ultimately, their athletes tend to perform better than athletes with inefficacious coaches. Interestingly, research on coaching efficacy also provides some support for the existence of a *Pygmalion effect,* whereby athletes internalize the cognitions of their coaches. Specifically, when coaches are confident in their capabilities, they tend to display more confidence in the abilities of their athletes. This, in turn, translates into athletes having more confidence in themselves.

Leadership: Transactional and Transformational

A noteworthy approach, and one that has only recently received sustained interest in the sports sciences, centers on the distinction between *transactional* and *transformational* leadership. Developed originally by the prominent organizational psychologist Bernard Bass, this model considers *transactional leadership* to involve the use of contingent rewards and corrective behaviors to eliminate problems and gain compliance among followers. *Transformational leadership,* on the other hand, involves actions that transcend one's own self-interests, whereby leaders influence others by elevating the goals of followers and empowering them to go beyond minimally accepted standards. According to Bass, transformational leadership is not a substitute for transactional methods. Instead, transactional leadership provides the basis for effective leadership, and transformational behaviors build on the transactional base in contributing to the extra effort and performance of individuals and teams. Transformational leadership consists of four components: (1) *idealized influence,* which involves engendering the trust and respect of others through the demonstration of personally held values and beliefs; (2) *inspirational motivation,* which involves providing a compelling vision of the future and displays of optimism about what others can accomplish; (3) *intellectual stimulation,* which involves engaging the rationality of others by encouraging them to think about old problems in new ways; and (d) *individualized consideration,* whereby leaders recognize the needs of others and display genuine care and compassion. In sports settings, transformational leadership behaviors, as displayed by coaches, have been found to result in higher levels of intrinsic motivation among athletes, increased performance, a reduced likelihood of athletes aggressing and engaging in injurious acts, as well as improved ratings of coach effectiveness. What is particularly interesting about this body of research evidence, and has particular relevance for coaching development programs, is that transformational leadership can be taught and developed through workshop-based and mentoring interventions.

Exercise Instructor Behaviors

While the majority of leadership research in the field of sports science has centred on understanding the determinants and consequences of coaching effectiveness, a growing body of enquiry has also centred on the nature of leadership behaviors within more general exercise- and health-related settings. In particular, research has examined the relationships between exercise instructor behaviors and class member adherence. Effective exercise instructors have been found to use socially enriched leadership styles, whereby the psychological needs and aspirations of group members are met. Examples of such behaviors might include using participants' names, giving frequent individual attention, providing positive feedback, and recognizing and rewarding participants' efforts.

Conclusion

Over the past few decades, several theoretical models concerned with the study of leadership have been proposed and empirically tested. However, four key features appear to pervade these diverse approaches. First, leadership happens at both an *individual* and a *group* level. Second, leadership is a *process* that can change or direct the behavior of individuals. Third, leadership is fundamentally *interpersonal,* requiring interaction and communication between the leader and individuals (or groups). Finally, leadership focuses on *achievement;* it is concerned with directing individuals toward set objectives or goals. In light of the prominent role of leaders in sports and exercise contexts and their effects on follower cognition, motivation, and behavior, the study of leadership remains a fruitful area of research.

Mark R. Beauchamp and Katie L. Morton

See also Anger and Violence in Sports; Psychological Assessment in Sports; Psychology of the Young Athlete; Sport and Exercise Psychology

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Lean Body Weight Assessment

The muscles, bones, ligaments and tendons, tissues, and water of the body make up *lean body weight*. Conversely, the amount of fat in the body is the *fat body weight*. Muscle tissue is 18% to 20% denser than fat. A liter (L) of muscle weighs about 1.06 kilograms (kg), whereas 1 L of fat weighs about 0.9 kg.

People may of course look very different even though they have the same height and weight. While one may look soft and "pudgy," another may be thin and muscular. Thus, body composition cannot be determined accurately simply by standing on the scale and measuring one's weight. In studying body composition, body mass is usually divided into two categories: the fatfree mass (FFM) and the fat mass (FM).

Body fat decreases and muscles become more developed in a person who is exercising to get fit. Pants may become tighter and the waistband may become looser. This informal measure of lean body weight may be good enough for many people. However, a more formal test, called body fat composition test, is needed for athletes and for those who are serious about their fitness.

Body composition is determined using several methods, the four most common of which are as follows.

Skin Fold Thickness

To measure skin fold thickness, the thumb and forefinger are used to grasp the skin and the nearby underlying tissue, pulling it away and pinching it using calipers that apply a constant pressure of 10 grams per square millimeter. Each site is measured twice to get more accurate and reproducible measurements. However, the accuracy of the measurements using this method depends on the skill of the measuring person and the part that is measured. Additionally, a very large increase or decrease in the skin fold thickness can increase the error. Several equations are used to predict body FM from skin fold measurements, but certain equations are recommended.

Underwater Weighing

The first method of underwater weighing was described in 1961. This method is based on Archimedes's principle that the volume of an object submerged in water equals the volume of water displaced by the object. The difference between the weight measured in water and the weight measured in air, after correcting for the water's density, is the body volume. In this system, a stainless steel tank filled with water is used. The subject kneels on a cot on top of strain gauges at the bottom of the tank. When using this technique, it is necessary to measure the lung volume under water. This contributes approximately 1 to 2 L to the total body volume. A pneumatic valve system is used to measure this residual lung volume with the underwater weighing.

Electrical Impedance

Electrical conduction in a biological conductor (a living organism) is related to its content of electrolytes and water; the more the electrolytes and water, the better is the electrical conduction. In bioelectrical impedance, only the body's FFM is measured because fat conducts electricity poorly and the FFM holds most of the body's water and electrolytes.

The ratio of the voltage to the current flow on a pair of terminals is called impedance and is expressed in ohms. Impedance, in direct current (DC) circuits is identical to resistance, but in alternating current (AC) circuits, it is a function of resistance, capacitance, and inductance. In AC circuits, voltages from the inductors and capacitors oppose the flow of current; this is called reactance. Impedance is calculated by combining reactance with resistance. There are many theories behind the use of impedance for body mass measurement and the calculations used to measure impedance.

To measure electrical impedance, aluminum electrodes are placed in the middle of the back of the hands and feet near the knuckles, on the inside of the wrist about one third of the way out, and between the two prominent bones of the ankle. Then, 800 microamperes of current at 50 kilohertz is run through the electrodes, and the resistance and reactance values are measured. Calculating conductance using the lowest resistance value allows the prediction of FFM.

Conclusion

Age, sex, and height are taken into account in all these methods that require calculations. Lean and fat percentage is the result. A man has a normal body fat of 8% to 15% and a woman, 13% to 20%. Fat percentages below 10% may be seen in elite female athletes and as low as 3% in elite male athletes. The normal range is what most people aim for. Taking up regular aerobic exercise and decreasing the fat in one's diet helps bring the fat percentage down if a person is above the normal range.

George Guntur Pujalte and Julie Ann Young Jardeleza

See also Dietitian/Sports Nutritionist; Nutrition and Hydration; Weight Gain for Sports; Weight Loss for Sports

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Legal Aspects of Sports Medicine

The term *sports medicine* encompasses the activity of many individuals from a number of professions who provide a variety of services or products. It includes physicians and other health care providers such as chiropractors, physical therapists, and podiatrists, as well as product salespersons and a diverse group of service providers.

Accordingly, any review of the legal aspects of sports medicine must necessarily involve a preliminary examination of the term *sports medicine* itself, which might be succinctly and broadly defined from a legal standpoint as follows:

> The provision, primarily of medical or allied health care to athletes, exercisers, recreational enthusiasts and others and the delivery of preventive, primary or rehabilitative care related to the prevention, treatment or rehabilitation of injuries and conditions related to sport, exercise or recreational activity, as well as the rendition of service and advice for fitness and training purposes to individuals who desire to engage in the aforementioned activities, and secondarily, the provision of medically or non-medically related services or products to those who are interested or involved in sport, exercise or recreation even though in this latter sense, the use of the term "medicine" may be inherently inappropriate. (*Legal Aspects of Sports Medicine,* 1995, by D. L. Herbert, p. 8)

Commentators and organizations that have looked at this topic area have also determined to define sports medicine in such a way as to make it broader than the mere medical treatment of just injuries and more comprehensive than the treatment of injuries related solely to participation in sports since most of the definitions that have been offered include not only services provided for the treatment of injuries but also the provision of services related to illness and injury prevention as well as rehabilitation. In addition, many definitions include activities that are broader than just participation in sports and include activities related to fitness, recreational pursuits, and other similar pastimes or endeavors. Some of these definitional references for the term *sports medicine* can be located in a number of journals, magazines, and other professional publications and were nicely summarized in a 2000 publication ("Australian Sports Medicine Specialty Faces Political Hurdles," published in *The Physician and Sports Medicine*).

For the purposes of this entry, sports medicine does involve the provision primarily of health care–related services to those sports, fitness, and recreation participants in need of medical, surgical, preventive, and rehabilitative treatment or service. As such, it is primarily carried out by those who are licensed and regulated at the state level through various state-enacted health care provider practice laws and administrative regulations. However, others who are not so regulated are also involved to some degree in the provision of activities that could be included within the broad umbrella of sports medicine services. In this latter context, such individuals may include exercise physiologists, clinical exercise physiologists, personal fitness trainers, athletic trainers, and others, some of whom are licensed or otherwise regulated and some of whom are not so licensed or regulated.

Any examination of the legal aspects of sports medicine must primarily concentrate on using a medical/health care model to discuss various legal concepts that affect primarily those in the health care provider sector. Sports medicine activities in this context involve a number of functions that are carried out through those providing sports medicine services. These include pre-activity screenings; pre-activity clearance decisions based on those screenings; preventive techniques designed at increasing the strength, stamina, and athletic/fitness capacity of those about to engage in activity; maintenance of levels of minimal or even optimal sports or fitness readiness/participation, detection, treatment, and rehabilitation of a variety of injuries or conditions that affect those participating in sports; and provision of related services ancillary to any of these main functions. Some of these particular service areas involve a number of heightened legal concerns that should be briefly examined and include, among others, issues related to informed consent/screenings/clearance for participation and return-to-participation decisions as made by sports medicine health care providers. Each of these subject areas involves certain legal issues, and each has resulted in claims, lawsuits, and court decisions. These cases have in turn established certain sports medicine legal concepts and, in some cases, legal precedents. An examination of these topics should be of assistance to this overall discussion.

In this context, it is important to mention that the delivery of sports medicine services is affected in substantial part by reference to various practice guidelines, standards, position statements, or parameters of practice. A significant number of these statements have been developed and published in the medical/health care provider field since the last quarter of the 20th century. The trend has continued to this date.

There are literally hundreds of practice statements directly or indirectly applicable to the field of sports medicine. These statements have been developed by a number of professional associations, including the American Academy of Family Physicians (AAFP), the American Academy of Pediatrics (AAP), the American Academy of Podiatric Sports Medicine (AAPSM), the American Academy of Sports Physicians (AASP), the American College of Cardiology (ACC), the American College of Sports Medicine (ACSM), the American Heart Association (AHA), the American Medical Association (AMA), the American Medical Society for Sports Medicine (AMSSM), the American Orthopaedic Society for Sports Medicine (AOSSM), and the American Osteopathic Academy for Sports Medicine (AOASM), among others. Similar statements have also been promulgated by other groups involved in exercise activity, athletic training, sports, or recreation. These include the American Council on Exercise (ACE), the Aerobics and Fitness Association of America (AFAA), the American Athletic Trainers Association (AATA), the National Athletic Trainers Association (NATA), the National Strength and Conditioning Association (NSCA), the National Collegiate Athletic Association (NCAA), and many others.

All the standards statements developed by these and other groups attempt to define and delineate aspects of the care made available to client/patient populations by providers and to put forth statements defining acceptable service delivery to clients/patients in practice areas of concern (e.g., concussion recognition and treatment). Consequently, such statements also have the potential to be used as references to define the standard of care offered to patients from a legal perspective and then to be used to judge the quality of care provided by means of claims and litigation. Expert witnesses typically support their opinions as given in litigation on the basis of such statements, either to attack the care that is rendered in particular cases or to support that care.

Six sports medicine groups, the AAFP, AAP, ACSM, AMSSM, AOSSM, and AOASM, have all joined in the development and publication of a frequently cited sports medicine monograph statement titled *Preparticipation Physical Evaluation,* third edition, which is one of the principal practice statements for the delivery of specified sports medicine services. This statement is extremely important to this aspect of sports medicine service, reportedly since clearance decisions for about 12 million athletes are made per year. A fourth edition of this work was published in May 2010 (http://ppesportsevaluation.org/body.html).

A brief examination of the legal aspects of sports medicine follows.

Informed Consent

One of the very basic rights of all individuals whose rights are safeguarded through the American system of jurisprudence is the right to determine what will be done to or with one's body. As part of that right, each individual about to undergo some medical procedure is entitled to be provided with sufficient information to enable the person to determine whether he or she will choose to undergo such a procedure or treatment process.

The informed consent process involves the provision of relevant information as to the proposed treatment, the available alternatives to that treatment, and the risks and benefits associated with the treatment or with any decision to forgo treatment so as to enable the patient to make an informed decision about whether to undergo the treatment or procedure. The process is therefore a give-and-take one that involves the provision of information by a provider to a patient, who then weighs or evaluates that information and makes a decision about the care that will be provided to him or her.

In sports medicine, a number of cases have arisen in some situations as to whether or not health care providers have properly engaged in such a process with patient–athletes. In one such well-known case, a professional football player, Charles Krueger, contended in litigation that he was not provided with sufficient information to enable him to determine whether or not he should continue to participate in professional football given the injuries that he had suffered and the treatment provided to him during his many years of participation in that sport (see *Krueger v. San Francisco Forty Niners,* 1987).

Another case involved a young college basketball player (Hank Gathers) who died during participation in a collegiate basketball game. After his death, his estate filed a lawsuit contending that the athlete was not given sufficient information to enable him to determine if he should continue to participate in college basketball given his condition and the treatment provided to him, which his estate later contended was improper and led to his death (see "The Death of Hank Gathers: An Examination of The Legal Issues," 1990, by D. L. Herbert).

Screenings/Clearance for or Return to Participation

While these two cases also involved, among other things, issues related to whether the involved sports medicine practitioners should have cleared these particular patient–athletes to participate or return to participation, both cases were settled prior to full adjudication. As a consequence, no judicial rulings specifying the exact duties of sports medicine practitioners to patient–athletes in these particular cases were established as precedents. Each of these cases, however, emphasized the need for injured/ill athletes to be properly screened, evaluated, and cleared for participation or return to participation by sports medicine health care providers.

Sports medicine practitioners must provide athletes, like all patients in other contexts, with sufficient medical information to enable these athletes as patients to determine their own course of treatment and in this context also determine whether they will continue to participate or return to athletic participation. The information conveyed by the providers and the recommendations made to each athlete must be in-depth and complete and must be provided without undue interference from any other third parties, such as coaches, administrators, fans, parents, and even, in some cases, the athletes themselves, many of whom desire to participate despite injury or illness. In the course of making recommendations and clearance decisions in this regard, providers must exercise due caution and resist being influenced by the sometimes overwhelming desire of some athletes to be cleared to participate or continue to participate in sports. Sometimes, athletic awards, college scholarships, or even large financial incentives may be the motivation behind the competitive expectations and plans of these patient–athletes. However, sports medicine providers must base their decisions and recommendations solely on applicable medical standards and guidelines and the best interests of their patients. Otherwise, deficiencies in this regard can well be actionable from a legal perspective, as the previously mentioned two cases and a number of others readily demonstrate.

While the foregoing areas of sports medicine have involved a number of claims and litigations beyond merely the Krueger and Gathers cases, other factual scenarios have also resulted in legal claims and suits. These cases have arisen out of alleged improper clearance decisions based on negligence/malpractice (failure to follow the accepted standard of care); mismatching of athletic participants; improper rehabilitation; inappropriate or improper prescription of activity, exercise, rehabilitation, even preparticipation screenings; and a host of other issues.

Conclusion

Health care providers in all areas of relevant service provision, including those involved in the delivery of sports medicine services, are obligated to render competent service in accordance with the so-called standard of care. In the United States, the evaluation of the standard of care is based on a national standard and is generally determined by expert witnesses, most of whom use written statements, guidelines, or so-called *parameters of practice* to define the appropriate standard of care to be provided to patients in particular circumstances. While such statements can be used either as swords to attack the alleged substandard care that is provided to athletes or as shields to protect against claims and suits, the legal concerns related to the delivery of sports medicine care can be complex but can be properly managed through the delivery of appropriate services to athletes.

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See also Catastrophic Injuries; Fieldside Assessment and Triage; History of Sports Medicine

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Legg-Calvé-Perthes Disease

Legg-Calvé-Perthes disease (LCPD) is a form of osteonecrosis, or dying bone, of the hip that is found only in children. It is known by other names as well, including coxa plana, ischemic necrosis of the hip, osteochondritis, and avascular necrosis of the femoral head. It is caused by a block of the blood supply to the developing femoral head, resulting in injury to the bone from lack of blood and nourishment (avascular necrosis). The disease is self-limited and usually lasts 1 to 2 years.

Cause

The cause of LCPD is not known. Some mechanism, whether it is traumatic disruption of the blood supply or injury from infection around the blood supply, causes an interruption of blood flow to the head of the femur (the leg bone that connects the hip to the knee). No known effective prevention exists for LCPD.

Who Gets Legg-Calvé-Perthes Disease?

LCPD is generally diagnosed in children between the ages of 4 and 11 years. It is a rare disease that affects approximately 1 in 1,200 children. Boys are affected more than girls; only about 1 in 4 diagnosed children is a girl. Most children with LCPD are affected only in one hip. Approximately 15% of children with LCPD have it in both hips. Children who develop the disease are generally very active and athletic. Children who are small for their age, with delayed skeletal maturity, are more likely to get LCPD.

The disease is found more often in Asians, Eskimos, and Caucasians. A much lower incidence of the disease is found in Australian aboriginals, Native Americans, Polynesians, and African Americans. Furthermore, exposure to secondhand smoke is correlated with increased risk of LCPD.

Symptoms

The onset of LCPD is often insidious. The first symptoms are usually a limp and sometimes pain in the hip, groin, or knee (pain in the groin or knee stemming from a hip problem is called "referred pain" and is common with hip problems). Parents usually notice the limping while the child is playing. The child does not remember getting hurt in any particular incident. Some children have hip pain or referred pain, and some children have no pain at all. A child with LCPD may tend to bear less weight on the involved leg while standing and may prefer to stand or lie down with the affected leg externally rotated (turned outward).

Diagnosis

A physician performs a physical exam and often orders imaging tests for children with a limp and/or leg pain. For children with LCPD, the physical exam often reveals pain and decreased range of motion when the hip is internally rotated (turned in toward the midline of the body) and when the hip is abducted (moved straight out from the midline of the body).

The physician may order X-rays, an MRI, and/or a bone scan to help determine the diagnosis. X-rays and other studies may be normal if taken early in the course of the disease. Late stages of the disease can show extensive disruption of bone in the femoral head.

Determining Disease Severity

In general, younger children usually have milder involvement of the hip bone and an easier recovery because new bone growth typically reshapes better in younger children than in older children.

Several different classification systems are used to determine the severity of the disease and the prognosis. These classifications are based on the extent of bony disruption seen on X-ray during the course of the disease, and they help physicians to determine the prognosis and appropriate treatment for patients.

Treatment

Treatment of LCPD has four primary goals:

1. To reduce hip irritability
2. To restore and maintain hip mobility
3. To prevent the ball of the femoral head from extruding or collapsing
4. To regain the spherical shape of the femoral head

For young children with minimal symptoms and X-ray findings at the time of diagnosis, doctors will often take a "watch and wait" approach. They will recommend that the child reduces his or her activity level and follow the child closely for signs of disease progression. Physical therapy to maintain good hip range of motion is often also recommended.

Nonsurgical treatments for LCPD include crutches to treat pain associated with weight bearing on the affected leg, as well as casts, traction, and braces to help with range of motion in the hip.

Patients who are diagnosed late in the disease course or who fail to respond to nonsurgical treatment will be considered for surgery.

A *tenotomy* is a surgery that is done to release a muscle that has become weak and short from limping. Once the muscle is released, a cast is placed on the leg to allow the muscle to regrow to a more natural length. The cast is usually left in place for 6 to 8 weeks.

An *osteotomy* is a surgery that involves cutting the bone and repositioning it. This surgery is done to keep the head of the femur in the normal position within the hip.

Long-Term Outcomes

Studies on the long-term results of LCPD demonstrate that the incidence of patients with LCPD who go on to develop osteoarthritis later in life depends on two factors: (1) whether or not the ball of the femoral head reshapes well and (2) whether or not the ball fits well into the hip socket. If the ball does not reshape well but the socket's shape still conforms to the ball, patients will tend to develop mild arthritis in later adulthood. If the ball of the femoral head does not reshape well and does not fit well into the hip socket, patients usually develop degenerative arthritis before the age of 50.

As stated earlier, the younger the age of onset of LCPD, the better the prognosis. In general, most patients have a favorable outcome.

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See also Hip, Pelvis, and Groin Injuries; Hip, Pelvis, and Groin Injuries, Surgery for; Musculoskeletal Tests, Hip; Young Athlete

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Lightning Injuries

Injuries due to lightning strike constitute the most significant nature-related hazard in sport. Only floods cause more storm-related deaths in the United States. About 600 to 700 lightning strikes occur per year, with 10% of that number causing fatalities. While the likelihood of lightning strike is low, any strike should be considered a life-threatening emergency. Nearly all injuries occur outdoors, through water activities or standing under trees. Lightning injuries involve a direct current that contacts the body by direct strike, side flash, or ground current. Prevention, education, and the development of an emergency action plan are the most important methods to avoid injury.

Clinical Evaluation

Many different organ systems can be damaged by lightning strike:

Skin: Burns caused by lightning strike may range from first to third degree. There is often an entrance and exit location.

Musculoskeletal: Injuries may include fractures, compartment syndrome, muscle rupture, or extremity dislocation.

Otologic: Tympanic rupture is the most serious otologic injury. Vertigo and hearing loss are also common.

Visual: Corneal abrasion, retinal hemorrhage or detachment, hyphema, or dilated pupils may occur. Cataracts are a delayed response.

Neurologic: Neurologic system injuries may occur because nervous tissue has a low resistance to injury. Short-term memory loss, difficulty processing new information, irritability, and distractability are common. Occasionally, personality changes, poor concentration, depression, and difficulty returning to previous levels of function may lead to isolation and avoidance of previously enjoyed relationships or activities. Magnetic resonance imaging (MRI) and computed tomography (CT) scans often appear normal; therefore, clinical suspicion of neurologic changes is paramount.

Cardiovascular: Cardiac arrest is the most serious injury to the cardiovascular system. Resuscitation with an automatic external defibrillator (AED) and cardiopulmonary resuscitation (CPR) are necessary for survival. Elevated cardiac enzymes may also be present on laboratory evaluation.

Prevention of Injury

Preparation for avoidance of lightning injuries must be considered when outdoor activities are contemplated. The National Collegiate Athletic Association has recommended guidelines to prevent lightning hazards. These include the following:

1. Designate a person to monitor the weather and make decisions regarding interruption of sports activity. Make plans to shelter participants and spectators, as well as institute a lightning safety plan to announce warning signals.
2. Use www.weather.gov or the National Weather Service on a daily basis to monitor storm activity in the area.
3. Monitor thunderstorm "watches" (warning signs of severe weather) or "warnings" (reports of severe weather) and take the proper precautions.
4. Know where "safe" structures (buildings with electrically grounded facilities) are located.
5. In the absence of a "safe structure," a vehicle with a hard metal roof with the windows rolled up may prevent injury.
6. Avoid being the "highest point" in the area. Lying down in a ditch, getting out of the water, avoiding touching metal objects, and avoiding open windows and doors are all methods to limit the possibility of lightning strike.
7. If thunder is heard, consider preparing for evacuation. If lightning is seen, consider suspending activities. *The "flash-bang" method is used for measuring the lightning strike distance, which is defined as the time between seeing the lightning and hearing the thunder*

divided by 5. If the time between seeing the lightning flash and hearing the thunder is less than 30 seconds (i.e., 30/5 = 6 miles [mi; 9.66 kilometers, or km]), suspend activities, and relocate the participants.

8. Lightning may strike in the absence of rainfall and cloudy skies and may present 10 mi (16.09 km) from the rain shaft.
9. Avoid the use of landline telephones as they are a possible conduit to current. Cellular phones are safe alternatives.
10. Activities may be resumed 30 minutes after the last flash of lightning and sound of thunder.
11. It is safe to perform CPR and touch individuals who have been struck by lightning as they do not carry an electrical charge. ABCs (airway, breathing, and circulation) and notification of 911, as in all emergencies, are the hallmarks of emergency care.

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See also Emergency Medicine and Sports; Outdoor Athlete

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Little League Elbow

The number of organized sports for children and adolescents has increased dramatically over the past few decades, with millions participating each year. In addition, year-round single-sport training has become much more commonplace among this population, leading to much longer competitive seasons and higher intensities of competition. These factors, along with conditioning and training errors, have resulted in dramatically elevated numbers of pediatric sports–related injuries, especially overuse injuries.

Classic Little League elbow (LLE) refers to an overuse injury of the medial epicondyle (inside part of the elbow), which results from repetitive throwing. The injury occurs at the apophysis, which is a bony outgrowth to which muscles attach. There are several different apophyses throughout our body, but the one associated with LLE is found on the medial epicondyle of the humerus. LLE occurs most commonly in baseball players between the ages 8 and 16 years. It has been estimated that 20% to 40% of 9- to 12-year-old adolescent baseball players suffer from elbow pain.

Repetitive throwing motions can cause an apophysitis, or inflammation of the apophysis. Since this is located on the medial epicondyle, it is also referred to as a medial epicondylitis (inflammation of the inside portion of the elbow). The apophysis is especially susceptible to injury while the growth plates are still active. Similar apophyseal injuries occur at different locations during adolescence, affecting both the heel and the knee region (commonly known as Sever and Osgood-Schlatter disease, respectively). Limiting repetitions, teaching proper mechanics, and a general understanding of skeletal development are all necessary for early recognition of this condition. Early diagnosis and treatment are important for better outcomes and for preventing long-term problems.

Anatomy

The elbow joint is where the humerus and ulna bones connect. This connection, or articulation, is surrounded by a capsule, several ligaments, and also several muscle tendons, which together form the joint. When stress is placed on the outside of the elbow, it is the bony articulation between the humerus and ulna that stabilizes the joint. When stress is placed on the inside aspect of the elbow, as in throwing, the medial collateral ligament serves as the primary stabilizer. Several muscles provide secondary support during throwing. In adult throwing athletes, elbow injuries commonly occur because the excessive forces placed on these ligaments and tendons cause them to fall, resulting in injury. In children, however, growth plates and apophyses are still active and are usually injured before tendons or ligaments. This can have serious long-term implications if the stress continues.

Mechanism of Injury

The throwing mechanism places a lot of stress on the inside of the elbow. This puts tension on the medial structures, including the ligaments and the apophysis. While stress is placed on the inside structures, a corresponding compression results on the outside structures. Overuse syndromes occur from excessive stress placed on muscles, bones, ligaments, and other soft tissue support structures. In LLE, this stress is caused by pitchers throwing at maximal effort. Under a reasonable amount of repetitive stress, the body is able to adapt. With a high number of repetitions of large amounts of force, bone or soft tissue overload will occur. This results in tissue breakdown known as microtrauma. Continuing to overload these structures without adequate recovery periods will lead to continued tissue breakdown. As this pattern continues, injury eventually results. When this occurs in a young thrower's elbow, it results in LLE (Figure 1).

Signs and Symptoms

Although LLE is most commonly found in pitchers, it is also seen in all the other baseball positions as well as in tennis players and football quarterbacks. Athletes may present with an array of symptoms that could include pulling, popping, giving out, or mild tenderness around the inside portion of the elbow. They also may have a history of decreased throwing effectiveness, velocity, or distance. However, patients often will not present until they can no longer throw because of extreme pain. On physical exam, there will likely be point tenderness over the inside elbow and pain associated with resisted flexion and resisted pronation (turning the hand with the palm facing alternately up and down). If swelling or restricted range of motion is observed, then this can be an indication of a more advanced injury.

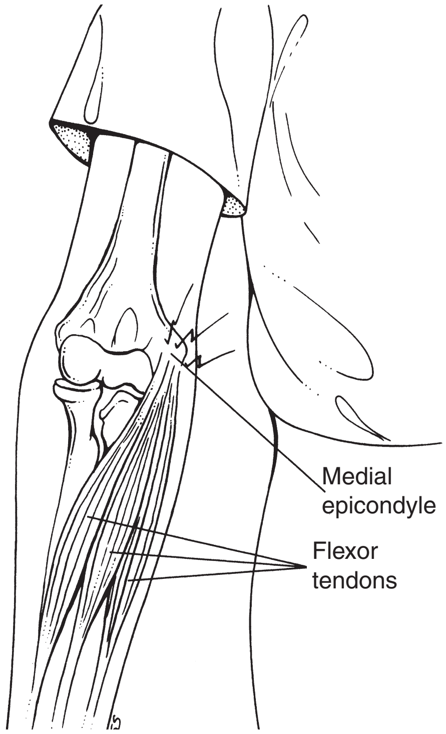

Figure 1 Little League Elbow

Notes: Little League elbow is the common term for damage to the growth cartilage on the inner aspect of the elbow of children and adolescents. If caught early enough, the separated growth cartilage can reattach.

Diagnosis

Diagnosing LLE is primarily done through the history and physical exam. The history would include when the symptoms started, what started them, and the progression until presenting to the physician. All pediatric and adolescent athletes complaining of any amount of medial elbow pain should be examined for LLE. In most instances, elbow X-rays should be taken from several different angles to make sure that there is no avulsion, loose bodies, or other bony changes. Any of these findings would complicate the injury and change the treatment plan. It is helpful to order X-rays of the opposite elbow as well so that the physician can compare the two sides, looking for abnormalities. X-ray films are found to be normal up to 85% of the time. A magnetic resonance imaging (MRI), computed tomography (CT), or bone scan of the elbow is rarely indicated in LLE but may be helpful if the patient fails to show signs of improvement after treatment.

Treatment

Treatment begins with rest from throwing that typically lasts 2 to 6 weeks. During this time, the athlete should be encouraged to begin or continue general conditioning, endurance training, and core strengthening exercises. Ice application on the area and nonsteroidal anti-inflammatory medication may also be helpful for pain and inflammation. Range-of-motion exercises followed by some stretching and strengthening exercises with resistance bands or light dumbbells are usually performed during the resting period. After the prescribed period of rest, a slow progressive throwing program should be implemented for several weeks before return to competition. During this time, the thrower's mechanics should be evaluated and corrected to decrease the chances of a recurring injury. The average time to return to unrestricted play is 12 weeks.

Complications

Most complications arise from a thrower returning to competition too soon or continuing to play while symptomatic. Continuing to throw with pain is associated with increased risks of more serious injuries that may require surgery.

Prevention

Preventing LLE should be a priority in all Little League throwing athletes. This is best achieved by first making sure that all pitchers are taught to incorporate proper form and mechanics. Next, core and muscle strengthening and stretching exercises should be implemented. This should include year-round conditioning with proper warm-ups prior to pitching. The most important aspect of prevention is monitoring the total number of competitive pitches that are being thrown both in practice and in games. The current recommendations for 8- to 14-year-olds ranges from 50 to 75 pitches in a game, 75 to 125 in a week, and a total for all age-groups of 1,000 pitches for an entire season. Although the risk of throwing breaking pitches at a young age is still not fully known with regard to Little League elbow, the USA Baseball Medical and Safety Advisory Committee currently recommends that pitchers under 13 should throw only fastball and change-ups. It further recommends that those under 10 should throw only fastballs.

As players, parents, and coaches work together, Little League elbow may in large part be prevented from becoming a problem.

Jeffrie C. Kindred

See also Elbow and Forearm Injuries; Elbow and Forearm Injuries, Surgery for; Musculoskeletal Tests, Elbow; Young Athlete

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Little League Shoulder

Little League shoulder is a clinical entity in which there is proximal humeral (shoulder bone) pain associated with throwing and there is radiographic evidence of a widened proximal humeral physis (growth plate). The diagnosis is typically made by history and physical exam findings. However, chronic changes such as demineralization, sclerosis, or fragmentation of the proximal humeral metaphysis (the flared end of a long bone) can also be seen on plain X-ray. It is not certain whether Little League shoulder is caused by inflammation secondary to overuse or a stress injury at the proximal humeral physis. Little League shoulder has also been described as proximal humeral epiphysitis, proximal humeral epiphyseolysis, and rotational stress fracture of the proximal humeral epiphyseal plate. If properly diagnosed and treated, Little League shoulder is a benign and self-limiting condition. However, if proper time off from throwing is not given, Little League shoulder may develop into premature closure of the proximal humeral physis and, thus, growth retardation of the humerus.

Anatomy

The shoulder joint comprises the head of the humerus as well as the glenoid fossa of the scapula (shoulder blade), hence the term *glenohumeral joint*. It is a classic ball-and-socket joint, and it is the most mobile joint in the body. The humerus is a typical long bone and like all long bones consists of a diaphysis, metaphysis, physis (growth plate), and epiphysis. The *diaphysis* is defined as the main shaft of the long bone. The *metaphysis* is considered the flared end of the long bone. The *physis* is the growth plate where expansion of the bone takes place in the skeletally immature. This appears as a radiolucent gross horizontal line on plain X-rays. The physis is not visible in adults. Last, the *epiphysis* is the end of each long bone.

The rotator cuff muscles attach at the epiphysis of the proximal humerus and aid in pulling the head of the humerus into the glenoid fossa. Little League shoulder does not involve the rotator cuff muscles. However, the condition does affect the physis and possibly epiphysis, without injury to the rotator cuff muscles of the shoulder.

Causes

Little League shoulder is a clinical entity caused by inflammation secondary to overuse or a stress injury at the proximal humeral physis. In theory, chronic overuse of the shoulder in a skeletally immature child causes strain in the weakest area of the glenohumeral joint, which happens to be the

Table 1 Recommended Maximum Number of Pitches With Respect to the Age of the Athlete

Age (years)	*Pitches per Game*	*Pitches per Week*	*Pitches per Season*	*Pitches per Year*
9–10	50	75	1,000	2,000
11–12	75	100	1,000	3,000
13–14	75	125	1,000	3,000

Source: Based on USA Baseball Medical and Safety Advisory Committee Guidelines of May 2006.

Notes: Pitch count limits pertain to pitches thrown in games only. These limits do not include throws from other positions, instructional pitching during practice sessions, and throwing drills, which are important for the development of technique and strength. Backyard pitching practice after a pitched game is strongly discouraged.

Table 2 Recommended Minimum Number of Rest Day(s) After Throwing a Certain Number of Pitches in a Game

Age (years)	*1 day of rest must be observed after throwing . . .*	*2 days of rest must be observed after throwing . . .*	*3 days of rest must be observed after throwing . . .*	*4 days of rest must be observed after throwing . . .*
≤14	21–35 pitches	36–50 pitches	51–65 pitches	≥ 66
14–18	31–45 pitches	46–60 pitches	61–75 pitches	≥ 76

Source: Based on 2010 Little League Baseball Regular Season and Tournament Pitching Rules.

Table 3 Proper Age to Learn Certain Types of Pitches

Pitch Type	*Age (years)*
Fastball	8
Change-up	10
Curveball	14
Knuckleball	15
Slider	16
Screwball	17

Source: Guide for patients and parents. Preventing Little League shoulder and elbow. *Contemp Pediatr.* 21(9). Copyright © 2004 Advanstar Medical Economics Healthcare Communications.

Note: Throwing curveballs and sliders, especially with poor mechanics, puts the pitcher at an increased risk of injury.

physis. An inflammatory cascade causes pain and tenderness to the proximal physis with any overhead activity or, if severe, even at rest. The long-term sequelae of a physeal injury are the possibility of premature closure of the physis and, thus, growth retardation of the humerus.

Symptoms

Little League shoulder typically occurs in patients between the ages of 11 and 16. Although classically this clinical syndrome occurs in baseball pitchers, it can also arise in a baseball player of any position, racquet sports players (i.e., tennis, badminton), swimmers, and even gymnasts.

Symptoms typically occur over several months and consist of progressive pain and discomfort at the proximal humerus with throwing, especially with high-velocity pitches and at higher pitch counts. The symptom of pain usually worsens to the point where the child develops pain even with light throwing and at low pitch counts. Furthermore, pitch control and command are lost as symptoms advance.

In addition, the symptoms of pain and discomfort can occur at any point of the pitching motion. Initially, the symptoms of pain resolve over the course of 24 hours. However, increased recovery time is evident as the child continues to throw with this condition. An athlete who has rested a few days may not present with pain to the physician. Moreover, it is not uncommon to receive the history of a child who is on multiple baseball teams during the season and plays a throwing sport year-around.

Diagnosis

Little League shoulder should be suspected when the above symptoms are elicited from the patient and his or her parents. On physical exam, there can be tenderness to palpation of the lateral aspect of the proximal humerus. There can also be discomfort with internal or external rotation against resistance with the shoulder at 90° of abduction. Furthermore, simple abduction of the shoulder at 90° against resistance may also be distressing.

However, there is typically no effusion, muscle atrophy, or loss of active or passive range of motion. There may be some discomfort when testing the strength of the rotator cuff muscles, but this is not due to a rotator cuff injury, which is exceedingly rare in a skeletally immature child.

When Little League shoulder is suspected, plain anteroposterior radiographs of both shoulders in internal and external rotation should be taken for comparison. Classically, a widening of the proximal humeral physis will be seen, although symptoms may precede radiographic changes. On occasion, chronic changes such as demineralization, sclerosis, or fragmentation of the proximal humeral metaphysis can also be seen. Magnetic resonance imaging (MRI), computed tomography (CT), and SPECT (single-photon emission computed tomography) are not needed to make the diagnosis of Little League shoulder and should not be ordered.

Treatment

The treatment for this condition is almost always nonsurgical. The athlete should be taken out of sports that require any kind of throwing or swinging of the symptomatic shoulder. It is recommended that these activities should be avoided for a period of at least 3 months. Nonsteroidal anti-inflammatory drugs or acetoaminophen can be started briefly for acute pain relief.

Physical therapy can be started when the patient is clinically asymptomatic. Rotator cuff strength, scapular stability, and general shoulder flexibility should be emphasized during physical therapy. However, if the patient has any symptoms of discomfort at the proximal humeral physis during therapy, then shoulder rehabilitation should be temporally discontinued.

Before gradual progressive throwing can be reinstituted, the patient needs to be completely asymptomatic on physical exam. This includes testing for apprehension, range-of-motion limitations, and weakness or discomfort in the rotator cuff muscles. Gradual progressive throwing is defined as subtle increases in the number of pitches, the types of pitches, the throwing distance, and the pitching velocity over a 1- to 2-month period. Any return of symptoms during this planned pitching should warrant a return visit to a physician for a repeat physical examination. Depending on the severity of the symptoms and the physical exam findings, a decision will be made about further rest and rehabilitation or the need to back down pitch count, distance, or the types of pitches being thrown.

Last, the decision to allow the athlete to resume throwing should not be based on radiographic evidence of healing, which may take several months. In fact, proximal humeral physeal widening is possibly an adaptive change in throwing athletes and, thus, would signify a normal finding if not associated with any symptoms. Again, Little League shoulder is mostly a clinical diagnosis.

Prognosis

If properly diagnosed and treated, Little League shoulder is a benign and self-limiting condition. Greater than 90% of athletes who develop Little League shoulder are asymptomatic on return to sports. The most prominent long-term sequela of Little League shoulder is premature closure of the affected proximal humeral physis. Although not many long-term studies have been done on this condition, it appears that premature physeal closure is an extremely rare complication after proper treatment.

Pitch count limitations, the number of rest days between pitching outings, and a gradual increase in the types of pitches thrown are the keys to preventing upper extremity pathology in a young athlete. Tables 1 to 3 provide pitching recommendations for injury prevention.

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See also Baseball, Injuries in; Musculoskeletal Tests, Shoulder; Shoulder Injuries; Shoulder Injuries, Surgery for; Young Athlete

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Liver Conditions, Hepatitis, Hepatomegaly

The liver, which is involved in numerous bodily functions including metabolism, aiding in digestion, and removal of toxic substances, can be affected by a variety of conditions causing liver enlargement (hepatomegaly) and inflammation of the liver (hepatitis). Common causes include infection, toxins as in alcohol abuse causing cirrhosis, malignancy (cancer or tumors), steatosis (fatty liver), and trauma. It is important not to allow an athlete with an acutely enlarged or damaged liver to participate in sports because of risk of rupture and threat of further severe injury.

The liver is the largest internal organ in the body and is located in the right upper quadrant of the abdomen just below the diaphragm under the right costal margin and to the right of the stomach. Normally, the liver, soft and smooth in consistency, can be slightly palpated just below the ribs, though in certain conditions, the liver can be enlarged with a tender edge, suggesting inflammation as in hepatitis, or firm and hard with irregular borders and nodules, indicating a malignancy. Other symptoms of liver abnormalities, particularly from infection and alcohol abuse, include yellowing of the skin and eyes, called *jaundice*. A detailed history is essential for an evaluation, with attention to the use of vitamins, supplements including anabolic steroids, or medications; alcohol and drug use; sexual activity; family history; and any history of blood transfusions. Further work-up includes laboratory studies to check liver enzymes, viral hepatitis serologies (blood serum), a complete blood count, image testing such as ultrasonography, and possibly a liver biopsy. With acute hepatitis, the athlete should have no evidence of hepatomegaly, along with normal liver function tests, before safely returning to play. There is also risk of transmission of certain acute viral hepatitis infections to teammates and opponents.

Cases have been reported of vigorous and endurance exercises creating a temporary increase in liver enzymes, causing a pseudohepatitis. The levels of liver enzymes return to normal within 3 days of stopping the exercise.

Liver trauma in athletes occurs with a direct blow to the right upper quadrant of the abdomen or lower ribs or from a deceleration force seen in noncontact sports such as cycling and snowboarding. Most commonly, hepatic contusions and hematomas result though liver lacerations, and rupture can occur, causing intra-abdominal bleeding and hemodynamic instability. Fortunately, the majority of liver injuries stop bleeding spontaneously. Persistent right upper quadrant tenderness along with nausea and vomiting need further evaluation, including an abdominal ultrasound or a computed tomography (CT) scan. Treatment consists of rest, observation, intravenous fluids, and, rarely, surgery to control bleeding. Full healing of the liver injury needs to be documented before allowing the athlete to return to play.

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See also Hepatic Injury; Hepatitis

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Lower Back Contusion

In everyday life, the lower back maintains posture in sitting, standing, walking; in sports, it has a wide variety of functions. For the throwing athlete, proper transfer of forces from the lower extremity to the upper extremity requires energy transmission through the muscles. Back injuries are very common, accounting for about 10% to 15% of sports injuries. It has been estimated that about 7% of injuries involve muscle contusions. Overall, muscle contusions represent up to 55% of all sports injuries. Fortunately, they are often minimally significant, demonstrating minor bruising. However, contusions will diminish the ability to condition the core, which is often overlooked in sports.

Muscle injury may be classified as contusion, strain, or laceration. *Lacerations* of back muscles are uncommon in sports. *Strains* are common and involve tensile overload forces that are applied to the muscle tendon unit; these are discussed in other entries of this encyclopedia. *Contusions* are caused by a traumatic impact or compressive force applied to the muscle.

Anatomy

The back gets its shape from the vertebral column, which includes the cervical spine of the neck, the thoracic spine of the chest, and the lumbar spine of the lower back. The lower back includes the lumbar vertebrae and sacrum. The smaller motion muscles of the back include the multifidi, which span only a couple of segments, and the larger muscles that span the entire circumference of the lower abdomen and back. Finally, there are the larger groups that connect the upper trunk and lower trunk, such as the latissmus dorsi and gluteus maximus.

Physiologic Response

Muscle tissue injury recovers by a process of repair. It does so in three distinct phases. The first phase is the destructive phase. There is acute rupture followed by necrosis of the muscle cells. This also involves variable collection of blood called a hematoma. Inflammatory cells also participate in this phase. The second phase is the repair phase, when the muscle cells are regenerated and there is connective tissue scar formation. The concern here is contracture with extensive scar. The third phase is the remodeling phase, in which the new muscle cells mature and the scar tissue remodels.

Common bruising is a minor contusion with capillary leakage of red blood cells. Most often, bruising is indeed minor and disappears in 2 to 4 weeks. However, certain individuals are more prone to bruising, such as women, children, elderly people, those taking blood thinners, and individuals with genetic bleeding disorders. Severe contusions may lead to pain and impaired movement due to scar tissue formation. Large hematomas may further limit motion and enhance scar formation. Rarely, a contusion with hematoma may stimulate bone formation in the muscle, called *heterotopic bone formation.* This latter entity is most common in the thigh and the elbow.

Clinical Presentation and Evaluation

Athletes will present with a history of a direct-impact injury. They will manifest localized pain, tenderness, and swelling. Discoloration may occur, with typical bruising progressing through four phases. Initially, it is bluish-red, followed by reddish-blue. It then turns to greenish-yellow and, finally, brown. These represent the breakdown phases of blood cells. Most significantly, the athlete will present with decreased movement. It is important to rule out an underlying, more significant injury. This would include spinal fracture and abdominal injuries such as a kidney laceration. An X-ray or bone scan should be considered to definitively rule out fractures. Fractures will usually manifest with tenderness to direct spinal palpation. If there is a question, a plain radiograph will help distinguish a fracture. Further imaging is often not needed. Magnetic resonance imaging (MRI) may aid in ruling out muscle tearing, but its expense often does not justify its use. A simple ultrasound image is an effective tool with minimal expense in the detection of hematoma and muscle disruption.

Treatment

Rehabilitation for a lower back contusion can usually be done from home. The initial phases of care should follow the RICE pattern of *r*est, *i*ce, *c*ompression, and *e*levation. This refers only to the first couple of days. Although early mobilization is helpful in muscle regeneration, a couple of days of rest will diminish scar tissue formation and risk of rerupture. Ice and compression during this time will limit swelling.

After the first 3 to 5 days, muscle activation is done in a sequential manner. Isometric strengthening is started, whereby the muscle is kept at a constant length with progressively more resistance, provided there is no pain. This may be accomplished with a simple bridging maneuver. Once this is painfree, isotonic strengthening is started with the muscle length changing while the tension remains constant. This is often done with theraband resistance. Finally, dynamic training is done when the first two phases are painfree. It is important to warm up the muscles first in these phases to allow flexible muscle motion and shock absorption. Stretching may be combined with warming to maximize the elasticity and diminish muscle contractures. If the athlete is unable to progress after the first 3 to 5 days of rest, careful attention should be given to looking for other problems such as a large hematoma that may need ultrasound drainage or occult fractures.

Application of alternating hot packs and cold packs at this stage may be helpful. This may assist in stretching the muscles. Early aerobic activity would include walking, swimming, and biking as able. One must stop if pain persists. Elastic bands and lumbar corsets can be used to assist with lower back support. These can be quite helpful in mobilizing the athlete. Medications such as an anti-inflammatory may be recommended in severe cases. Acetaminophen has been shown to be equally effective. Injection of corticosteroids will give an initial boost to pain reduction but will diminish the effectiveness of long-term healing with more disarray of the scar tissue. Electrical stimulation has been shown to be effective in strengthening the muscle during immobilization as well as in decreasing pain. Ultrasound treatments can increase blood flow to the area. Massage is also helpful in breaking up scar tissue. This is started with light traction and advances as the athlete's recovery progresses.

Strength training for the lower back should include bilateral arm lifts, alternate arm and leg lifts, prone on elbows, prone press up, roman chair, arm lifts, and leg lifts. Once the athlete has progressed through the strengthening phases, the sport-specific or functional phase must be addressed. In this phase, the athlete gradually mimics the motions that will be required in the specific sport.

Return-to-Sports Criteria

Ideally, the athlete should be painfree with full core strength and stability prior to returning to play. This will usually start with noncontact practice drills and is followed by progressively more contact time. If there is some residual tenderness, a corset brace or pad can be very useful when returning to sports.

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See also Back Injuries, Surgery for; Lower Back Injuries and Low Back Pain; Lower Back Muscle Strain and Ligament Sprain

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Lower Back Injuries and Low Back Pain

Low back pain is a very common complaint in the general population, as well as in athletes. Up to 85% of the population will experience back pain at some point in their lives. It can interfere with daily activities as well as training. Low back pain is the most common disability in those under 45 years of age. The incidence of low back pain in sports is about 10% to 15%, with certain sports having even higher incidences. Gymnastics, both artistic and rhythmic, have incidences of low back pain between 50% and 86%, whereas about 27% of college football players experience low back pain.

The causes of low back pain are significantly different between adults and youth. Bony injuries are more common in young athletes, whereas disk-related problems are relatively uncommon. Idiopathic pain is much less common among young athletes than in adults. Because structural injuries are more common in young athletes, investigations should be pursued earlier and more thoroughly in younger age-groups. The diagnosis of "back strain" in young athletes should be a diagnosis of exclusion to avoid missing serious structural injuries.

Lower back injuries occur as a result of acute trauma or from repetitive microtrauma or overuse. Acute trauma occurs most often in contact sports such as football, rugby, and hockey. Overuse injuries occur most often in sports with repetitive flexion, extension, and torsion, such as gymnastics, dance, and figure skating.

More sinister causes of low back pain should not be overlooked. Infection, neoplasm, visceral pathology, and inflammatory conditions can cause low back pain. "Red flag" symptoms such as fever, night pain, weight loss, and neurological symptoms should prompt investigation for these other serious conditions.

Risk factors for low back pain are listed in Table 1.

Anatomy

The lumbosacral or lower back spine comprises five lumbar vertebrae, the sacrum, and the coccyx. Occasionally, there may be anatomical variants, such as a sacralized fifth lumbar vertebra, a lumbarized first sacral segment, or a spina bifida occulta.

Each lumbar vertebra has both anterior and posterior elements. The vertebral body, intervertebral disks, and vertebral end plates constitute the anterior elements. The posterior elements include the facet joints and pars interarticularis. Between each pair of vertebrae is an intervertebral disk, the central core of which is the *nucleus pulposis,* a gel-like substance contained by the *annulus fibrosis,* concentric rings of fibrocartilage that enable the disk to act as a shock absorber, resilient to compressive forces. The interface between the disk and the vertebral body is formed by the cartilaginous end plates. Circumscribing the end plates is the cartilage ring apophysis, which eventually fuses with its vertebral body.

There are several bony prominences off the posterior arch that interconnect through multiple

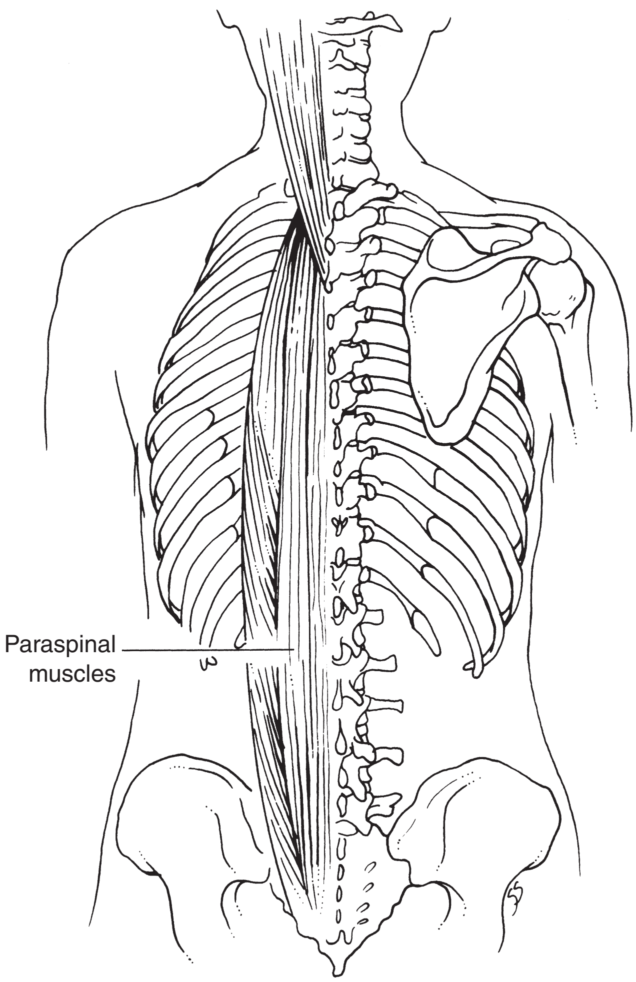

Figure 1 Paraspinal Muscles, or Erector Spinae

Notes: The paraspinal muscles both stabilize the spine and generate spinal movement. They work with a complex system of muscles in the chest, abdomen and pelvis to create spinal stability such as sitting and standing as well as bending and twisting motions.

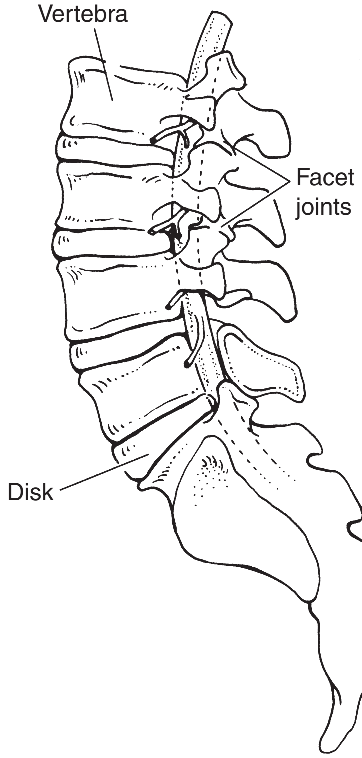

Figure 1 The Lumbar Spine

Notes: The lumbosacral spine consists of five lumbar vetebrae, the sacrum, and the coccyx. Many people associate low back– pain with the condition of the "slipped" or herniated disk, in which the a tear in the fibrocartilage around the intervertebral disk allows the soft nucleus pulposis to emerge and come into contact with nerve fibers.

ligaments. These ligaments offer stability to the spine. Furthermore, the ligaments have nerve fibers and provide a function called *proprioception*, which is the way the brain recognizes how the back is positioned at any given moment. This proprioception is critical for proper core muscle activation as the spine is subjected to various forces in sports activity.

There are a number of muscles around the spine. (Most of these are addressed in the entry Core Strength.) In short, the core muscles form a circumferential hydrostatic drum from the back round to the abdomen. These stabilize the spine and generate power to the upper and lower extremities. The pelvic muscles, such as the gluteus maximus and medius, stabilize the pelvis and aid in transfer of force. The latissimus dorsi and rectus abdominus transfer forces between the upper and lower trunk. The upper trunk refers to the shoulder girdle muscles.

The sacroiliac joints form part of the pelvic ring and have both a synovial portion and a ligamentous portion.

Physiology

Muscle injury is classified as a contusion, laceration, or strain. Contusions are discussed in the entry Lower Back Contusion. Lacerations to the lumbar muscles are exceedingly uncommon. Strains represent a shearing force to the muscle tendon unit. Every muscle transitions to a tendon at the muscle–tendon juncture. A tendon attaches from muscle to bone. The tendon crosses a joint, and muscle contraction occurs to provide joint motion. Conversely, a ligament attaches from bone to bone, and an

Table 1 Risk Factors for Low Back Pain

Risk Factors
Sedentary occupation
Heavy physical labor; jobs involving bending, twisting
Periods of growth
Muscle imbalances, inflexibility (hamstring tightness, hip flexor tightness, thoracolumbar fascia tightness)
Sports involving repetitive spinal extension, rotation
Volume of training (increased back pain with increased training hours)
Poor technique
Biomechanical abnormalities (genu recurvatum, increased femoral anteversion, increased thoracic kyphosis)

injury to it is referred to as a sprain. Muscle strains occur in the lower back when a sudden motion occurs that applies a shear force to the muscle–tendon juncture and ruptures it in this location. This is usually reflective of chronic overload, which may occur with deconditioning and postural imbalances. Muscle strains also often occur when the muscles are fatigued, such as late in a competition.

After a strain to the muscle, tissue recovery follows three sequential phases. The initial phase is the destructive phase, with muscle necrosis and inflammation. The second phase is the repair phase, with production of new muscle cells and scar tissue formation. The final, and longest, phase is the remodeling phase. Treatments are aimed at minimizing the destructive phase and enhancing the repair and remodeling phases.

Ligamentous injuries have similar repair processes of inflammation, repair, and remodeling. They are classified as Grade I, with minimal intrasubstance tear; Grade II, with a partial tear but some contiguity of the fibers; and Grade III, with a complete rupture. After a ligamentous tear, the ligaments repair with an immature Type III collagen, possibly predisposing to repetitive injury.

Evaluation of Injuries

Details of Injury

Low back pain can result from various causes. The onset of symptoms can help distinguish between acute trauma and more gradual, insidious causes. Details of the pain, including its duration, location, quality, and severity, as well as aggravating and relieving factors, and any neurological symptoms, such as numbness or shooting pain, can also help determine the cause of low back pain.

An athlete's activity, including the type of sport, position played, volume of training, and level of competition, may predispose him or her to back injuries. In particular, recent increases in the volume or intensity of training or changes in training can result in back pain. A history of menstrual irregularities, disordered eating, and previous stress fractures may indicate the presence of female athlete triad, which may predispose an athlete to stress fractures.

A family history of human leukocyte antigen B27 (HLA-B27)-associated conditions, such as inflammatory bowel disease, psoriatic arthritis, or ankylosing spondylitis, may suggest the possibility of a rheumatological cause for low back pain. The presence of any "red flag" symptoms suggests more sinister causes of low back pain, such as infection or cancer. Other causes of back pain include kidney disease, bowel disease, and gynecological disease.

Physical Findings

Athletes with low back pain may have abnormalities of gait and posture, such as a limp or unsteady gait. When looking at the back from behind, the athlete's pelvis and shoulders may not be level, and there may be asymmetry of the bony and soft tissue structures on either side of the spine. There may be skin abnormalities, such as hairy patches, skin dimples, hemangiomas, or café au lait spots, which may indicate spinal pathology. There may also be spinal abnormalities, such as scoliosis, kyphosis, or excessive lordosis. From the side, there should be a gentle lumbar lordosis. To assess for scoliosis, an Adam forward bending test can be performed to look for a rib hump. The examiner stands behind the patient as the patient bends forward with the arms hanging down.

Range of motion of the spine includes flexion, extension, lateral flexion, and rotation. Athletes should be able to flex forward, keeping their knees straight, and touch their toes, but tight hamstrings may limit forward flexion. Low back pain associated with flexion suggests injury to the anterior elements of the spine or muscle strain/spasm. Extension-related back pain suggests injury to the posterior spinal elements or the sacroiliac joint. A single-legged hyperextension test can assess for possible injury to the posterior elements. The athlete stands on one leg and extends through the spine. A positive test elicits pain in the back of the ipsilateral leg.

Palpation of the spine and sacroiliac joints may elicit areas of tenderness. Palpation of the soft tissues, such as the paraspinal muscles and buttocks, may also elicit tenderness and muscle spasm.

Special tests in the examination of the lumbar spine include the FABER (*f*lexion, *ab*duction, *e*xternal *r*otation) test, the Gaenslen sign, and the straight-leg test. The FABER test and the Gaenslen sign assess the sacroiliac joint. The FABER test is performed with the patient lying supine, with the hip flexed, abducted, and externally rotated and the foot resting on the opposite knee. The examiner then presses the flexed knee into the table while stabilizing the opposite hip. A positive test elicits pain in the back on the ipsilateral side of the flexed leg.

The Gaenslen sign is also performed with the patient in the supine position. The patient holds one leg with knee flexed to his or her chest while the opposite leg is extended over the edge of the table. The examiner applies downward pressure on the leg hanging over the table edge. A positive test elicits pain in the back on the ipsilateral side of the hanging leg.

The straight leg raise test assesses for neural tension. The patient lies supine, and the examiner raises one of the patient's legs until the patient reports severe back or buttock pain or the knee starts to bend. The examiner then dorsiflexes the ankle to determine if the pain has increased. A patient with no neural tension should be able to raise the leg close to 90° without pain.

Back injuries can sometimes involve the spinal cord and nerves. There may be abnormalities of sensation and strength, and deep tendon reflexes of the lower extremities. There may be marked tightness of the hamstring muscles. If low back pain is referred from the hip, there may be decreased range of motion of the hip or pain with hip movement. Back pain that is referred from abdominal organs may result in tenderness at the costovertebral angle (the area next to the spine below the ribs) or abdominal tenderness.

Investigations

X-rays are the most common investigation ordered for low back pain. In younger athletes with symptoms lasting more than a couple of

Table 2 Lower Back Injuries

Common	*Uncommon*	*Cannot Be Missed*
Spondylolysis (stress fracture of pars interarticularis)	Disk prolapse	Malignancy
Sacroiliac joint pathology	Spondylolisthesis	Infection (osteomyelitis, diskitis)
Disk pathology	Spinal canal stenosis	Osteoid osteoma
Hip pathology	Acute vertebral fractures	Osteoporosis
Contusion	Rheumatological	
Muscle strain/ligament sprain	Visceral pathology (gastrointestinal, genitourinary, gynecological)	

weeks, X-rays should be done to rule out structural injuries. In acute injuries where fractures are suspected, X-rays should be done.

A computed tomography (CT) scan can be helpful to diagnose bony injuries such as pars interarticularis fractures and acute fractures. This modality can be used to monitor progress of healing of fractures, although it involves a significant amount of radiation.

Bone scan with SPECT (single-photon emission computed tomography) is a very sensitive test for diagnosing structural injuries such as pars interarticularis fractures, as well as infectious processes.

Magnetic resonance imaging (MRI) can elucidate soft tissue injuries such as disk herniations. Clinical correlation is required, however, as MRI can often overcall abnormalities.

Types of Injury

A list of injuries of the lower back is given in Table 2.

Treatment

Treatment of muscle strains and ligament sprains is managed in a similar fashion. During the first few days, there is relative rest to allow for the muscle tendon unit and ligaments to start repair with minimal inflammation and muscle necrosis. During this time, the principles of RICE (*r*est, *i*ce, *c*ompression, and *e*levation) are maintained. Elevation usually refers to injury to the limbs. The ice and compression work by limiting the swelling.

After the first couple of days, early mobilization is initiated. The intense spasm is addressed with different heating mechanisms, including moist heat, ultrasound, and electrical stimulation. Another strong adjunct during this early phase is joint mobilization, which may be performed by those trained in joint mobilization, including osteopathic and chiropractic techniques. Massage may be very effective here as well. During this phase, the strengthening follows a typical pattern, starting with isometric training, where the muscle contracts with no motion, such as a bridging posture. Once this is mastered without pain, isotonic training is started, with muscle motion but constant resistance, such as theraband exercises. Once this is mastered without pain, dynamic strength training is started. Throughout these strengthening progressions, stretching is performed through the zone of comfort and enhanced by warming the muscle groups before the stretch. This warming enhances muscle viscosity and shock absorption. In the athlete who has difficulty progressing, a corset brace with a posterior molded plastic pad is helpful in giving security for increased motion.

Medications may also be considered. Although somewhat controversial, nonselective nonsteroidal anti-inflammatory medications such as ibuprofen and naprosyn appear to assist in the rehabilitative process without diminishing ligamentous healing. Other good analgesics such as acetaminophen or stronger tramadol may be considered. Muscle relaxers should be used for significant spasm. Cyclobenzaprine is useful at night to assist with sleeping.

Once the athlete has progressed with advanced strengthening, the sport-specific or functional phase of rehabilitation is addressed. Here, the athlete will start on plyometric exercises as well as drills that mimic the specific sports activity. This is a commonly missed step in rehabilitation, which may predispose the athlete to recurrent injury.

Prevention of Injury

Most back injuries and back pain in athletes can be prevented. Before each sports season, a preparticipation evaluation may identify certain risk factors, such as previous injuries that have not been fully rehabilitated, or muscle weaknesses or inflexibility. These factors can then be corrected before the season starts. Athletes should also begin general strength and fitness conditioning to get ready for the season. The frequency and intensity of training should be gradually increased to allow for safe adaptation to the demands of the sport.

In younger athletes who are still growing, loss of flexibility and muscle imbalances associated with growing can predispose them to injury. Therefore, young athletes should reduce the amount of training and the volume of repetitive motions during periods of rapid growth. Core-strengthening exercises and hamstrings and hip flexor stretches may help reduce the risk of low back pain.

Proper technique is very important to avoid injury. For all athletes, correct posture limiting excessive lordosis of the lumbar spine can help prevent injuries to the lumbar spine. In sports requiring lifting, such as dance and pairs skating, proper lifting techniques must be used to prevent back injuries.

Return to Sports

Recommendations regarding return to play for an injured athlete must take into account the diagnosis, the sport or activity, and the amount of cooperation from the athlete and coaches in allowing activity modifications during healing. As part of the rehabilitation process, risk factors such as muscle imbalances and inflexibilities should be identified and corrected.

Generally, relative rest is necessary to allow for healing. Activities causing pain should be avoided until the athlete can participate without pain. With modifications of the activity, most athletes are able to continue in their sport. Bracing is often used to allow healing while the athletes continue in their sport. Good core strength must be demonstrated by a number of tests, such as a stable single-leg squat, holding a crunch position with stability, and maintaining a neutral spine for at least 1 minute on the roman chair. As the rehabilitation program proceeds, the athlete should progress through sport-specific training prior to resuming sports activity. The athlete should demonstrate proper technique for the sport-specific activity. For instance, the crew athlete should demonstrate good pelvic posture during the catch and layback phases of the stroke. Furthermore, muscular endurance should be demonstrated by the ability to maintain this posture for prolonged periods on the erg machine. Finally, return to competition should be approached in a progressive manner by applying the general rule of increasing the amount of time in activity by about 10% per week. When the athlete has attained painfree range of motion with all activities and has regained full strength, he or she can return to full sports participation.

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See also Back Injuries, Surgery for; Core Strength; Lower Back Contusion; Lower Back Injuries and Low Back Pain; Lower Back Muscle Strain and Ligament Sprain

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Lower Back Muscle Strain and Ligament Sprain

Back pain in the athlete is a common finding, and muscle injuries are one of the most common causes of back pain. Muscle injury may involve a contusion or a strain of the muscle. A contusion represents a traumatic blow to the spine. Although there is often an acute moment that the athlete recalls as the onset of pain, a strain usually represents a chronic overload with an acute episode, when it is recognized. Ligamentous sprains about the spine usually represent an acute overload to the spine. Although these are usually benign injuries, incomplete recognition and rehabilitation often lead to chronic pain and poor athletic performance. This is usually due to the reflex inhibition of the surrounding core muscles.

Anatomy

The spinal column consists of the 7 cervical vertebrae, 12 thoracic vertebrae, 5 lumbar vertebrae, and the sacrum. Low back pain refers to pain around the lumbar spine and sacrum. The spinal vertebrae are composed of the vertebral body and the posterior bony arch. This arch forms the spinal canal for the traversing spinal cord and nerves. The anterior vertebral body is separated from the level above and below by intervertebral disks. The posterior arch or canal is separated from the adjacent levels by the two facet joints. There are several bony prominences off the posterior arch, that interconnect through multiple ligaments. These ligaments offer stability to the spine. Furthermore, the ligaments have nerve fibers and provide a function called proprioception, which is the way the brain recognizes how the back is positioned at any given moment. This proprioception is critical for proper core muscle activation as the spine is subjected to various forces in sports activity. The intervertebral disk itself is a series of well-organized concentric ligament sheaths that surround the gelatinous inner substance.

There are a number of muscles around the spine; these form a circumferential hydrostatic drum from the back around to the abdomen. These stabilize the spine and generate power to the upper and lower extremities. The pelvic muscles, such as the gluteus maximus and medius, stabilize the pelvis and aid in transfer of force. The latissimus dorsi and rectus abdominus transfer forces between the upper and lower trunk. The upper trunk refers to the shoulder girdle muscles.

Physiology

Muscle injury is classified as contusion, laceration, or strain. (For a discussion of contusions, see the entry Lower Back Contusion.) Lacerations to the lumbar muscles are exceedingly uncommon. Strains represent a shearing force to the muscle tendon unit. Every muscle transitions to a tendon at the muscle-tendon juncture. A tendon attaches from muscle to bone. The tendon crosses a joint, and muscle contraction occurs to provide joint motion. Conversely, a ligament attaches from bone to bone, and an injury to the ligament is referred to as a sprain. Muscle strains occur in the low back when a sudden motion occurs that applies a shear force to the muscle-tendon juncture and causes a rupture in this location. This is usually reflective of chronic overload that may occur with deconditioning and postural imbalances. Muscle strains also often occur when the muscles are fatigued, such as late in a competition.

After a strain to the muscle, tissue recovery follows three sequential phases. The initial phase is the *destructive* phase, with muscle necrosis and inflammation. The second phase is the *repair* phase, with production of new muscle cells and scar tissue formation. The final and longest phase is the *remodeling* phase. Treatments are aimed at minimizing the destructive phase and enhancing the repair and remodeling phases.

Ligamentous injuries have similar repair processes of inflammation, repair, and remodeling. Ligamentous injuries are classified as Grade I, with minimal intrasubstance tear; Grade II, with a partial tear but some contiguity of the fibers; and Grade III, with a complete rupture. After a ligamentous tear, the ligament repairs with an immature Type III collagen, possibly predisposing to repetitive injury.

Clinical Presentation and Evaluation

Athletes with a ligamentous sprain or muscle strain will present with acute back pain. They will usually recall one moment of pain onset but may have some preceding, milder pain. The pain is very positional and worsens with activity. While swelling is a common finding with contusions, spasm is a common association with sprains and strains of the spine. This spasm may be quite debilitating. Typically, the athlete will manifest no boney spinal tenderness and will lack any neurologic symptoms such as numbness or weakness.

If there is any question of spinal tenderness or trauma, a plain X-ray should be performed. Further imaging is most often not useful. Most ligamentous sprains and muscular strains will resolve in the first couple of weeks, and advanced imaging is not needed. However, in the unusual case when pain lasts longer than 3 to 6 weeks, further imaging is indicated. If a disk problem is considered, a magnetic resonance imaging (MRI) scan is useful. A bone scan is very helpful in detecting stress fractures. This is discussed in the Lower Back Injuries and Low Back Pain entry.

Treatment

Treatment of muscle strains and ligament sprains is managed in a similar fashion. During the first few days, there is should be relative rest to allow for the muscle tendon unit and ligaments to start repair with minimal inflammation and muscle necrosis. During this time, the principles of RICE (*r*est, *i*ce, *c*ompression, and *e*levation) are maintained. Elevation usually refers to injury to the limbs. The ice and compression work by limiting the swelling.

After the first couple of days, early mobilization is followed. The intense spasm is addressed with different heating mechanisms, including moist heat, ultrasound, and electrical stimulation. Another strong adjunct during this early phase is joint mobilization, which may be performed by those trained in joint mobilization, including osteopathic and chiropractic techniques. Massage may be very effective here as well. During this phase, the strengthening follows a typical pattern, starting with isometric training, where the muscle contracts with no motion, such as a bridging posture. Once this is mastered without pain, isotonic training is started, with muscle motion but constant resistance, such as theraband exercises. Once this is mastered without pain, dynamic strength training is started. Throughout these strengthening progressions, stretching is performed through the zone of comfort and enhanced by warming the muscle groups before the stretch. This warming enhances muscle viscosity and shock absorption. If an athlete has difficulty progressing, a corset brace with a posterior molded plastic pad is helpful in giving security for increased motion.

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Once the athlete has progressed with advanced strengthening, the sport-specific or functional phase of rehabilitation is addressed. Here, the athlete starts on plyometric exercises as well as drills that mimic the specific sports activity. This is a commonly missed step in rehabilitation and may predispose the athlete to recurrent injury.

Return-to-Sports Criteria

The athlete with a muscle strain or ligamentous sprain should satisfy certain criteria prior to returning to competition. First, the athlete must be relatively painfree. Occasionally, a corset-type brace may also be used in the early stages of returning to competition. Good core strength must be demonstrated by a number of tests, such as a stable single-leg squat, holding a crunch position with stability, and maintaining a neutral spine for at least 1 minute on the roman chair. Furthermore, the athlete should demonstrate proper technique for the sport-specific activity. For instance, the crew athlete should demonstrate good pelvic posture during the catch and layback phases of the stroke. Furthermore, muscular endurance should be demonstrated by the ability to maintain this posture for prolonged periods on the erg machine. Finally, return to competition should be approached in a progressive manner by applying the general rule of increasing the amount of time in activity by about 10% per week.

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See also Back Injuries, Surgery for; Lower Back Contusion; Lower Back Injuries and Low Back Pain

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Lower Leg Injuries

Lower leg pain is a common complaint in athletes. Both shin and calf pain can persist for months if not appropriately managed. Injuries can be acute, such as fractures of the tibia or fibula, or chronic, resulting from repetitive microtrauma. Traumatic injuries usually occur in contact sports, such as football, rugby, and soccer, and sports such as skiing and snowboarding. Overuse injuries usually occur in sports involving a lot of running and jumping, such as cross-country running, track-and-field events, and basketball. Training errors and inappropriate equipment may contribute to the occurrence of these injuries.

Shin pain can result from acute injuries, resulting in fractures of the tibia and fibula. Nonacute, overuse injuries of the shin usually result from recurrent impact loading, leading to bone stress.

The most common causes of calf pain are injuries to the muscles and tendons. Muscle strains are very common and usually result from a sudden burst of acceleration, such as stretching for a ball in racquet sports. The calf is also a common area of contusions resulting from contact with equipment or other players. Cramping and delayed muscle soreness also frequently occur in the calf.

Anatomy

There are two bones in the lower leg: the tibia and fibula. They are covered by only a thin layer of skin and subcutaneous tissue. Most of the lower leg muscles control ankle and foot motion. The gastrocnemius muscle also flexes the knee. The gastrocnemius is the most likely muscle to be strained in the lower leg.

The muscles of the lower leg are contained in four compartments, separated by fascia. The anterior compartment contains the primary dorsiflexors of the foot: the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius muscles. These muscles are supplied by the deep peroneal nerve, which is also the sensory nerve for the dorsal web space between the first and second toes. The lateral compartment contains the most important evertors of the foot: the peroneus longus and brevis muscles. The superficial peroneal nerve, a sensory nerve, is also contained in the lateral compartment. The peroneal nerve bifurcates into the deep and superficial branches at the level of the fibular head. At this point, the nerve is quite superficial and is tented across the bone. The superficial peroneal nerve enters the lateral fascia of the lateral compartment at the midpoint of the lower leg and continues to the lateral ankle, where it branches to supply sensation to the distal lateral foot. The superficial posterior compartment contains the medial and lateral heads of the gastrocnemius, which originates on the femur; the soleus, which originates in the lower leg; and the plantaris muscle. The gastrocnemius and soleus have a common

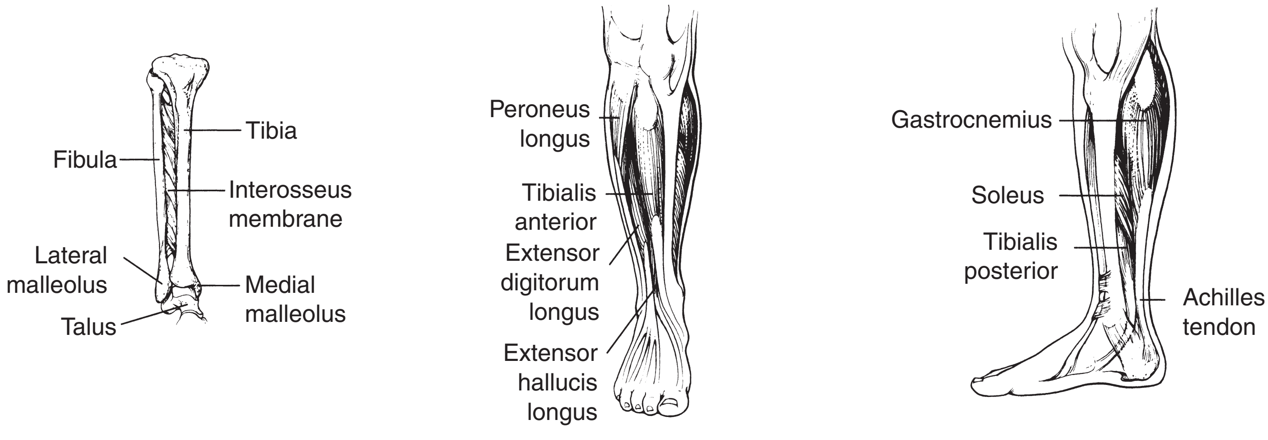

Figure 1 Lower Leg Anatomy

Notes: (a) The tibia carries almost all of the weight in the body, while the fibula acts as a stabilizing agent. The tibia is the second largest bone in the body (next to the femur). (b) The muscles of the lower leg are contained in four compartments. The calf muscle was named *gastrocnemius*, or "stomach of the leg," for its bulging shape.

tendon, the Achilles tendon, which attaches to the calcaneus. The deep posterior compartment contains the tibialis posterior, flexor hallucis longus, and flexor digitorum longus muscles. There may be a "fifth" compartment, a subcompartment of the deep posterior compartment formed by the variable fibular attachment of the flexor digitorum longus.

Blood is supplied to the lower leg mainly by the popliteal artery. It branches into the anterior and posterior tibial arteries at or just below the popliteal fossa. The anterior tibial artery travels through the anterior compartment and is palpable as the dorsalis pedis pulse. The posterior tibial artery travels through the deep posterior compartment and is palpable adjacent to the medial malleolus. The large saphenous vein runs superficially over the distal medial leg.

Evaluation of Injuries

Details of Injury

The mechanism of injury, the duration of symptoms, as well as the location and character of the pain can help differentiate the cause of lower leg pain in athletes. The timing of the pain, its relationship to different activities, and whether or not the pain resolves or recurs with activity, can help determine the cause of the pain. There may be associated symptoms, such as numbness, tingling, or muscle hernias. Sudden-onset pain usually is indicative of an acute injury, such as a fracture, muscle tear, or tendon rupture. Gradual-onset pain is more indicative of an overuse injury, such as stress fracture or chronic exertional compartment syndrome.

Previous injury to the same area may predispose the athlete to recurrent injuries, particularly if previous treatments and rehabilitation were incomplete or ineffective.

Lower leg pain may be a symptom of some other underlying concern. "Red flags" include loss of regular menses in females, excessive leanness or obesity, unusual constellations of symptoms and physical findings (night pain, loss of sensation, weakness), an athlete who does not make eye contact, or a parent who speaks for the athlete. These may indicate a systemic disorder, such as osteogenesis imperfecta or Ehlers-Danlos; a psychological disorder, such as anorexia nervosa or depression; or overtraining syndrome. Lower leg pain may also be referred from the lower back or hip.

Physical Findings

Alignment of the legs may make an athlete more prone to lower leg injuries. Bowlegs (genu varus), knock-knees (genu valgus), flat feet (pes planus), and tibial torsion (rotation of the bones) are some alignment conditions that may be seen in an athlete with a lower leg injury. There may be color changes of the skin and decreased muscle bulk, as well as swelling, bruising, or asymmetries. Comparing the injured leg with the noninjured leg can highlight the differences. Abnormal color may indicate reflex sympathetic dystrophy. Loss of muscle bulk may represent atrophy.

An athlete with a lower leg injury may walk or run with a limp or be unable to bear weight. Hopping may reproduce pain, or the athlete may not be able to hop because of weakness or pain. Pain may also be associated with activity such as calf raises and running on a treadmill or in the hall.

The bones, muscles, and tendons of the lower leg may be tender to palpation. Point tenderness of the tibia or fibula may represent a fracture or stress fracture. There may be irregularities of the skin and subcutaneous tissues, including temperature or texture changes, swelling, or edema. There may also be palpable defects in the muscles or tendons.

Range of motion of the foot and ankle may be decreased with lower leg injuries. A high-arched or cavus foot is usually somewhat rigid and has limited shock absorption, which increases the impact pressure on the bone. Excessive pronation of the foot (rolling inward) causes the superficial and deep compartment muscles to be lengthened, necessitating more forceful contraction to perform, and over time, muscle fatigue leads to decreased shock absorption. Ligament injury may result in excessive motion or decreased motion secondary to pain. Resisted muscle movements may demonstrate weakness and exacerbate pain.

Special tests in the evaluation of a lower leg injury include the stress fracture test, the Thompson test, the Homans sign, and the slump test (neural tension test). The stress fracture test involves applying a vibrating tuning fork along the tibia. In the setting of a stress fracture, this may exacerbate pain in the bone. The Thompson test involves squeezing the calf and noting whether or not ankle plantarflexion (toes pointed down) occurs. Absence of ankle plantarflexion indicates a complete tear of the Achilles tendon or musculotendinous junction. The Homans sign involves extending the knee and adding overpressure to dorsiflex (toes pointed up) the ankle.

The slump test is performed by having the patient sit on the examining table with the arms behind the back. The neck is flexed forward and then the leg is extended, with the ankle being dorsiflexed. A positive test results in reproduction of neural symptoms in the extended leg, such as shooting pain, numbness, or tingling.

Investigations

X-rays are inexpensive and are commonly performed to investigate lower leg pain; however, they are often negative or only subtly positive. Bone scans are usually performed when stress injuries are considered. Bone scans are sensitive but not specific. Stress injuries are indicated by increased uptake, which may be discrete in stress fractures or more diffuse in periostitis (inflammation of the bone).

Ultrasound imaging is beneficial for soft tissue injuries such as muscle hematomas and tears.

Magnetic resonance imaging (MRI) is advocated because of its sensitivity in diagnosing soft tissue injuries as well as bone lesions. Whereas X-ray and bone scan cannot diagnose soft tissue disorders, MRI can indicate muscle strain or herniation, as well as benign and malignant tumors.

The diagnosis of chronic exertional compartment syndrome is confirmed by intracompartmental pressure measurement, the gold standard test. Pre- and immediate postexertion measurements are essential to confirm the diagnosis.

Additional investigations that may be considered for more unusual causes of leg pain include electromyography (EMG)/nerve conduction studies (for nerve entrapments), venous Doppler ultrasound (for deep vein thrombosis), and laboratory tests such as complete blood count (CBC; for infections), erythrocyte sedimentation rate (ESR; for inflammatory or rheumatological disorders), and electrolytes (for hypokalemia [low potassium], hypocalcemia [low calcium], and hypomagnesia [low magnesium]).

Types of Injury

A list of injuries of the lower leg is given in Table 1.

Table 1 Lower Leg Injuries

Lower Leg Region	*Common*	*Less Common*
Shin	Acute fractures	Popliteal artery entrapment
	Stress fracture/stress reaction	Muscle herniations
	Medial tibial periostitis	Pes anserine bursitis
	Chronic exertional compartment syndrome	Tumors
	Muscle strains	Infection
	Tendinopathies (peroneal)	Acute compartment syndrome
Calf	Muscle strains	Deep venous thrombosis
	Gastrocnemius	Achilles tendon rupture
	Soleus	Achilles bursitis
	Muscle cramps	
	Muscle contusion	
	Delayed muscle soreness	
	Achilles tendinopathy	

Prevention of Injury

Athletes should be properly conditioned to ensure the development of sufficient strength, flexibility, and endurance to meet the demands of their sport. The athlete should gradually and progressively increase the amount of time spent doing repetitive sport skills and should learn new skills at a safe rate, allowing for sufficient motor learning as well as tissue adaptation. The appropriate protective equipment for the particular sport should be worn and properly maintained. General health should be maintained, including having proper nutrition, maintaining an appropriate body mass index, ensuring regular menses in the case of female athletes, ensuring adequate sleep, and allowing enough recovery time following sports activity.

Return to Sports

The first goal in the treatment of all injuries is to achieve painfree status. As soon as the athlete is painfree, rehabilitation can progress. Some conditions may require immobilization and non–weight bearing for a period of time. Following immobilization, a protective brace or other device may be required. As symptoms improve, the athlete can participate in more activities. Return to sports is allowed when the athlete can ambulate without a limp, pain does not recur with activity, no medications or modalities are used to mask the pain, and the athlete is able to advance through a therapeutic exercise program without increase in his or her symptoms.

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See also Achilles Bursitis; Achilles Tendinitis; Achilles Tendon Rupture; Calf Strain; Exertional Compartment Syndrome, Chronic; Medial Tibial Stress Syndrome

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Lower Leg Injuries, Surgery for

The lower leg consists of the portion of the lower extremity between the knee and ankle joints. The skeleton of the lower leg is formed by the tibia and the fibula bones. The tibia is larger than the fibula and is the major weight-bearing bone of the lower leg. The tibia articulates with the femur above to form the knee joint and with the talus below to form the ankle joint. The tibia is triangular in cross section and can easily be felt along the front portion of the lower leg.

The fibula is cylindrical in cross section and is mostly covered with muscle, but it can be felt on the outside portion of the leg at its two ends. The fibular head is just below the knee, and the lateral malleolus forms the outer aspect of the ankle. The fibula plays an important role in ankle stability through its bony articulation with the talus as well as its ligamentous connections to the foot. It does not articulate directly with the knee joint, but the lateral collateral knee ligaments do attach to the fibular head.

The tibia and fibula are connected to each other at two joints—the proximal (upper) and distal (lower) tibiofibular joints—and by a sheet of connective tissue, called the *interosseus membrane,* that spans the distance between the tibiofibular joints. The interosseus membrane transmits forces between the two bones, which can become apparent in certain ankle injuries. Rotational forces exerted on the foot can be transmitted from the lower end of the tibia, up the interosseous membrane to the top of the fibula, resulting in a fracture at the upper end of the fibula. The round fibular head sits in a shallow groove on the tibia to form the proximal tibiofibular joint. The distal tibiofibular joint is intimately associated with the ankle joint.

The muscles of the lower leg are separated into four compartments by enveloping layers of tissue called *fascia*. The anterior (front) compartment contains the muscles responsible for flexing the foot and toes upward (dorsiflexion). The muscles of the lateral (outside) compartment rotate the foot in an outward direction (eversion). The posterior (back) muscles flex the foot downward (plantarflexion). The deep posterior muscles flex the toes downward and rotate the foot in an inward direction (inversion). In general, the nerves and blood vessels travel deep in the muscular compartments, with the exception of the common peroneal nerve, which wraps around the outer aspect of the fibular head and is vulnerable to injury by a direct blow.

Lower Leg Injuries

Most athletic injuries of the lower leg are due to overuse. The tibia transmits much of the force from the foot's impact with the ground during running and jumping, making it vulnerable to injury from repetitive loading. In fact, the tibia is the most common site of stress fracture in athletes. A stress fracture is a small break in the bone that may or may not travel across the entire bone. Bone is constantly being broken down and re-formed throughout the skeleton. Stress fractures occur when microscopic injuries to the bone occur faster than the body can heal them. Inadequate nutrition for the demands of the sports activity, the training surface, changes in training intensity or regimen, the anatomic alignment of the legs and feet, bone density, and belonging to the female sex have all been associated with stress fractures. Stress fractures cause activity-related pain with tenderness over a focal area and may progress to complete fractures (see below). Stress fractures may not always be visualized on regular X-rays but can be seen on bone scans or magnetic resonance imaging (MRI). Most stress fractures can be treated by relative rest along with modification of training techniques. Immobilization in a brace may be required.

Medial tibial stress syndrome—commonly referred to as shin splints—is also related to overuse. Muscles that attach along the posteromedial (inner and back) portion of the tibia can become inflamed, causing activity-related pain in that area. Overpronation of the foot during running has been implicated as the cause of this inflammation. The area of tenderness is usually more diffuse than is the case with stress fractures. Diagnosis is usually made based on examination, but MRI or bone scan may be used to differentiate from other causes. Modifications of shoe wear or orthotics, relative rest, anti-inflammatory medications, and stretching of the lower extremity muscles typically resolve symptoms.

Chronic stress fracture of anterior tibia at risk for progression to complete fracture

Source: Children's Hospital Boston Division of Sports Medicine.

Note: The anterior tibial cortex on the left side of the figure is thickened, and a small black line is visible, extending part of the way through the cortex.

Chronic exertional compartment syndrome is caused by transient impairment of blood flow to the various compartments of the lower leg. During exercise, muscles swell. When the envelope of fascia surrounding the muscles is unable to accommodate the swelling, pressure builds up inside the compartment and limits blood flow to the tissues in the compartment. Patients usually notice aching pain in the affected compartment during exercise. The anterior and lateral compartments are most often involved. Symptoms usually begin several minutes into exercise and may persist for some time after cessation of exercise. The nerves traveling through each compartment can also be affected, causing numbness or tingling in various areas of the foot. Diagnosis is made by measuring the pressure in the compartments before and after exercise.

Intramedullary nail placement to stablilize fracture

Source: Children's Hospital Boston Division of Sports Medicine.

Muscle herniation occurs when the fascia surrounding the muscle becomes weakened, allowing an outpouching of the muscle. Hernias can be associated with compartment syndrome but can also occur independently. There are natural openings in the fascia where nerves leave the compartment and travel beneath the skin. Muscle herniation through such an opening can result in *nerve impingement,* which causes burning pain, tingling, or numbness in the area of the nerve. The common peroneal nerve can also be affected where it wraps around the fibular head.

Popliteal artery entrapment is a rare cause of leg pain in the athlete. The popliteal artery is the main artery that supplies blood to the lower leg. As it enters the lower leg, the artery can be compressed by enlarged or abnormal muscles. Cramping, aching, tingling, and numbness occur. Examination is often normal at rest, but changes in the pulses of the foot may be detected with activity or with flexion and extension of the ankle. Vascular studies or MRI are usually required to make the diagnosis. Symptoms of numbness, tingling, or weakness in the legs can also be due to nerve compression or blood vessel disease in the upper leg, pelvis, abdomen, or spine.

Gasctrocnemius-soleus (calf muscle) *strain* can cause acute pain in the athlete. Simultaneous stretching and active contraction of the muscle can cause a strain or tear, with the sensation of a pop being felt. Pain with variable amounts of bruising or defect in the muscle occurs. This injury can be mistaken for a rupture of the Achilles tendon, which connects the calf muscles to the foot, and is often treated surgically. Treatment with rest and gentle stretching usually resolves symptoms.

Acute fractures of the lower leg can occur during contact sports or in association with stress fractures. Treatment consists of either immobilization in a cast or brace, or surgery, depending on the nature of the fracture.

Most athletic injuries of the lower extremity are activity related. Pain that occurs at rest can be a sign of systemic disease, tumor, or other nonathletic causes.

Surgery for Fractures of the Tibia

Stress fractures of the tibia may require surgical fixation in cases of delayed healing—usually greater than 4 to 6 months—despite appropriate nonoperative treatment or in cases that are at high risk of progressing to a complete fracture. Stress fractures of the anterior (front) part of the midshaft of the tibia are considered high risk. Standard surgical treatment is placement of a rod down the shaft of the bone that traverses the fracture site (intramedullary nailing) and provides stability to the bone (see figure next page). Treatment of acute tibial fractures depends on the location and severity of the fracture but can include casting or surgical fixation with either intramedullary nailing or a plate and screws. Fractures of the upper and central portion of the fibula are treated nonsurgically. Fractures of the lower end of the fibula are considered to be ankle fractures and will be discussed in that section. Return to sports is allowed when the fracture has solidly healed on X-ray images, tenderness at the fracture site is resolved, and appropriate strength and range of motion have been attained, which usually takes at least 8 to 12 weeks.

Surgery for Compartment Syndrome

The unyielding fascia surrounding the leg muscles is often unresponsive to physical therapy and must be addressed surgically. Small incisions are made in the skin overlying the affected compartments, and the fascia is cut open over the majority of its length to allow the underlying muscle to expand. The anterior and lateral compartments may both be accessed through one incision, as can the superficial and deep posterior compartments. Return to sports is usually between 4 and 6 weeks.

Surgery for Nerve and Artery Entrapment

The location of entrapment must be identified based on clinical examination, imaging tests, or other studies. Surgery involves cutting a portion of the tight muscle or fascia to relieve pressure on the nerve or blood vessel. In advanced cases of popliteal artery entrapment, surgery may be required to repair damage to the vessel itself. Return to sports is variable based on the severity of damage.

Craig Finlayson

See also Achilles Bursitis; Achilles Tendinitis; Achilles Tendon Rupture; Calf Strain; Exertional Compartment Syndrome, Chronic; Medial Tibial Stress Syndrome

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Lung Injuries

Lung injuries, although rare in sports, can be serious. The basic function of the lungs is to add oxygen to the blood. This essential process depends on adequate flow of air to the air sacs (alveoli) in the lungs and adequate blood flow to the tissues surrounding the air sacs. Any injury that causes blood or fluid to leak into the alveoli, compresses the air sacs, or prevents adequate blood flow through the lungs will result in reduced oxygen supply to the blood and, ultimately, to other tissues of the body. Shortness of breath, chest pain, blue appearance to the skin (cyanosis), loss of consciousness, a rapid heart rate, or coughing up blood are all signs of possible lung damage and require immediate medical attention. The most common causes of injury to the lungs during sports are direct trauma, pressure changes, and decreased oxygen at high altitude.

Traumatic Injuries

Types of Injuries

The shearing forces of a blow to the chest can produce bruising or bleeding of the lung. Either may produce shortness of breath and coughing. If the bleeding is significant, there may be blood in the sputum. If the lung tissue is torn, air can leak into the chest cavity. This is called a *pneumothorax*. Air can leak around the lung or into the center of the chest. When it leaks into the center of the chest, it is called a *pneumomediastinum*. In this situation, air may be noted under the skin around the neck and chest. The skin feels crackly when this occurs. The medical term for this is *subcutaneous emphysema*. Occasionally, air continues to leak into the chest cavity, and this can cause the potentially life-threatening problem called a *tension pneumothorax*. In this case, air keeps entering the lung cavity, with no way to exit. As the pressure builds, the lung is compressed. In this situation, each breath a person takes will cause more air to leak into the lung, resulting in worsening shortness of breath. An opening into the chest wall must be made immediately to release the pressure and allow the lung to re-expand. Blood may collect between the lung and the chest wall. This is called a *hemothorax*. If the lung is bruised, it is called a *pulmonary contusion*.

A pneumothorax, tension pneumothrax, or hemothorax can also be caused by a puncture wound to the chest. The most common sports injury cause of this is a rib fracture, where a sharp piece of bone from the fracture tears the lung tissue.

Diagnosis

The first step in diagnosing lung injuries is to complete a history and physical exam. Signs of lung injury are decreased breath sounds, wheezing, or dullness to percussion. To percuss the lungs, the physician taps on the chest wall and listens to the difference in sounds on one side compared with the other. Normal lung tissue has a hollow sound. If fluid is present, there is dullness to percussion. Measurement of the oxygen content of the blood is often helpful. Chest X-ray is also an important diagnostic tool. The X-ray will show if there is air leaking from the lungs, if the lungs are being compressed, or if there is fluid accumulation around the lung. Occasionally, a computed tomogram of the chest is needed to see damage to lung tissue.

Treatment

The treatment depends on the size and type of injury. A small pneumothorax may be treated with observation. Once the lung tissue heals, the air leak seals and the body resorbs the air. A large pneumothorax, tension pneumothorax, or hemothorax are usually treated with a chest tube. The chest tube is inserted through the chest wall, between the ribs, and hooked up to a suction device. Air and fluid are removed from around the lung, allowing the lung to expand and heal. Once the lung has started to heal and air is no longer leaking from the lung, the chest tube can be removed. Supplemental oxygen is often needed in the early stages of treatment. Occasionally, surgery or medication placed around the lung may be needed to seal the air leak. The athlete is usually able to return to full sports participation once cleared by his or her physician. The healing time is typically 6 to 8 weeks after the injury.

A pulmonary contusion usually clears up on its own and does not require any specific intervention. However, if it is severe and the athlete's breathing is significantly impaired, a ventilator may be needed to help oxygenate the blood while the lung tissue heals.

Treatment of lung injuries due to puncture wounds from rib fractures is similar to the treatments listed above. Most often, the rib fracture will heal without the need for surgery.

Pressure Injuries

Types of Injuries

Lung tissue is sensitive to pressure changes as occurs in scuba diving. Air that is under pressure will expand when the pressure is reduced. This occurs when a diver breathes compressed air under water and then swims to the surface. Air in the lung will expand and potentially cause damage to the lungs. The diver must always exhale while coming to the surface, to allow the expanding air to escape from the lungs. Rupture of the lungs due to the expanding air can cause pneumothorax, subcutaneous emphysema, or pneumomediastinum. Another type of lung injury that can occur with diving is *air embolism*. In this case, gas bubbles suspended in the blood expand when the diver surfaces, and these bubbles, if large enough, can block the arteries in the lungs, preventing the lungs from functioning normally and providing air exchange. These bubbles can cause a blockage in any blood vessel in the body, but because of the large number of blood vessels in the lung, this is a common location for this problem to occur. This problem requires a decompression chamber for appropriate treatment.

Diagnosis and Treatment

The diagnostic and treatment steps for pneumnothorax are similar to those for traumatic injuries as outlined above.

Air embolism is a serious problem and requires immediate treatment. The usual presentation is shortness of breath and chest pain. Diagnostic tests such as chest X-ray may not be helpful. First aid is supplemental oxygen, aspirin, and hydration. Immediate transfer to a decompression chamber is the treatment of choice.

Lung Injuries Due to High Altitude

Types of Injuries

In settings where the oxygen content is relatively low, such as in high mountain regions, the lungs can become inflamed and leak fluid into the air sacs (high-altitude pulmonary edema, or

HAPE). When this occurs, the lungs' ability to provide oxygen to the blood is impaired, resulting in severe shortness of breath. These injuries occur in mountain climbers and high-altitude trekkers.

Diagnosis

The usual presentation is shortness of breath, fatigue, cough, bluish discoloration of the skin or lips, and, if severe, gurgling while breathing. Fluid in the lungs produces a characteristic sound, called rales, that the physician can hear when listening with a stethoscope. Chest X-ray will usually show fluid in the lungs. The problem is more likely to occur if the climber does not take time to let his or her body acclimatize or adjust to the lower oxygen content at higher altitudes.

Treatment

The treatment is to move the patient to a lower altitude and provide oxygen supplementation. Unfortunately, there is no preventive treatment that is 100% effective. Acclimatization rather than rapid ascent is helpful. At extremely high altitudes, climbers should use supplemental oxygen. Medications that have been used in the treatment and prevention of HAPE include salmeterol, acetazolamide, dexamethasone, and nifedipine.

Michael Henehan

See also Organ Injuries; Outdoor Athlete; Physiological Effects of Exercise on Cardiopulmonary System

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Malignant Brain Edema Syndrome

Malignant brain edema syndrome is a rare but possibly fatal complication that can occur in the setting of a single or recurrent closed-head injury. The term *malignant brain edema syndrome* was formerly associated chiefly with infants and children but has recently been expanded to include the entity commonly referred to as the *second impact syndrome*. Second impact syndrome is thought to occur if an individual sustains a second head injury while still suffering from the effects of a previous head injury from the recent past. Sudden increases in intracranial pressure resulting from diffuse cerebral swelling lead to catastrophic deterioration hallmarked by coma, brain herniation, and death. The physiologic cause of malignant brain edema syndrome is unclear, but several theories have been proposed. Early recognition and immediate medical attention are necessary to maximize a positive outcome.

Clinical Description

Malignant brain edema syndrome was first characterized in infants. The usual scenario was that of a child who experienced a mild head trauma. The child's condition would quickly deteriorate, presenting with fixed, dilated pupils and frequently with evidence of either flexor or extensor posturing. The syndrome was notable for the fact that there was severe swelling identifiable on brain imaging studies without other significant findings such as intraventricular bleeding, subdural hematoma, or subarachnoid hemorrhage to explain the clinical progression (these findings could be present but were insufficient to explain the degree of the noted swelling). Unlike subdural or epidural hematomas, which progress over the course of minutes to hours, malignant brain edema can result in clinical deterioration in seconds to minutes. Infants, in whom closure of the fontanelle has not yet occurred, may exhibit fewer clinical symptoms, being able to better accommodate increased intracranial pressure.

From a sports perspective, the more commonly encountered scenario begins with a contact sport athlete sustaining a mild traumatic head injury during practice or competition. The resulting concussion can produce a wide variety of symptoms, such as headache, nausea, memory loss, mood changes, or balance difficulties. The severity and duration of these symptoms are highly variable. The key event that is assumed to lead to second impact syndrome is a second hit to the head that occurs while the individual is still suffering form the effects of the first injury. After several minutes and without further provocation, the athlete has a sudden change in consciousness or may collapse. Invariably, the patient is described to have pupillary abnormalities, from alternating or unilateral pupillary dilation, to prominent hippus (the condition of alternating, almost rhythmic, dilation and contraction of pupils without changes in external light stimulus), to fixed and dilated pupils. There may be evidence of flexor (decorticate) or extensor (decerebrate) posturing, and the person may quickly lapse into a coma. Given the damage to the brainstem, respiratory compromise can occur. Without immediate medical attention, death ensues, although even with aggressive measures taken to ameliorate the increases in intracranial pressure, the outcome is frequently poor.

Instances of malignant cerebral edema have been reported most commonly in contact sports such as football, rugby, boxing, and hockey and also in noncontact, high–injury risk sports such as skiing. The overall rarity of the condition has made accurate estimations of frequency difficult. Information is derived mainly from case reports and retrospective case series. While the implications are unclear, it has been noted that no clear case of second impact syndrome has been reported in anyone over 18 years of age.

Pathophysiology

The pathophysiology of malignant brain edema syndrome is poorly understood. While several hypotheses exist as to the nature of this condition, uncertainty stems in large part from the fact that the underlying mechanism of concussion is itself not fully understood. One theory of concussion states that kinetic energy from a blow to the head results in distortion or strain on the axons within the brain, resulting in abrupt neuronal depolarization and an influx of calcium and water through the damaged neuronal membrane. These changes result in disrupted neurotransmission, release of excitatory neurotransmitters, changes in glucose metabolism, and significant alteration in cerebral blood flow regulation. The transient neurologic dysfunction that results manifests as the variety of symptoms mentioned above.

The second impact syndrome occurs in the setting of the impaired cerebral blood flow regulation caused by the initial concussion. A second blow to the head then results in near-complete loss of cerebral blood supply autoregulation, resulting in rapid vascular engorgement and a sudden increase in intracranial pressure with compression of the cerebral ventricles, leading to brainstem compromise. In reported cases, the timing of the second impact has been variable. More than one boxer who had second impact syndrome was believed to have had the second impact during the same bout. In other cases, several weeks were thought to have separated the first and second impacts.

As mentioned above, second impact syndrome is thought to occur primarily in a younger population. There are several possible explanations for this phenomenon, including the fact that until adulthood, the brain is continuing to establish its internal connections through the process of myelination. Also, the head-to-body ratio is higher in this population, and neck muscles are less developed, resulting in more angular rotation of the head during impact. The skull is thinner in younger populations, perhaps adding to the risk. Finally, pediatric patients tend to experience the effects of concussion for a longer period of time than adults, increasing the possibility of a second impact occurring during this extended period of vulnerability.

Treatment

Malignant brain edema syndrome is a rapid and frequently fatal process. Given the nature of the syndrome, the best chance for survival and recovery is with immediate medical attention and transport to a facility equipped to manage elevated intracranial pressures. These measures include intubation and artificial hyperventilation of the patient; administration of hypertonic saline and/or mannitol (both concentrated osmotic agents designed to "draw" fluid out of the brain); and, in certain cases, surgery (hemicraniectomy) to remove a portion of the skull in order to allow the brain to swell without putting pressure on the brainstem, thereby avoiding herniation. With the exception of the surgical procedure, these measures are temporary, and even with aggressive management, this condition is frequently fatal.

Prevention

Given the serious nature of the possible outcomes, every reasonable step should be taken to prevent malignant brain edema syndrome from occurring. Prevention begins by first addressing the prevention of concussion in general. In contact sports, no single modifiable risk factor is as important as proper technique. Engaging an opponent by leading with the head should be, in all circumstances, clearly emphasized as improper. Ensuring the availability of properly fitted and certified equipment is also essential. The rules that govern contact sports should also be critically evaluated to minimize the number of high-impact blows to the head. Even when these steps are taken, the fact remains that many of our sports, by their nature, will continue to carry a risk of brain injury.

When a concussion does occur, prevention of malignant brain edema syndrome, or second impact syndrome, should then turn to ensuring that the athlete is not put at risk of another head injury while still suffering from the effects of the first. Practically speaking, this means keeping the athlete out of practice and competition until he or she reports no symptoms either at rest or after a controlled test of physical exertion (e.g., a 30-minute ride on a stationary bike). In addition, objective data such as a scored balance test or neuropsychological markers can be used to help determine whether an athlete has returned to his or her preconcussion baseline. Such data should only be used as part of an overall management strategy under the guidance of a health care provider.

Aaron Mammoser and Jeffrey S. Kutcher

See also Concussion; Neurologic Disorders Affecting Sports Participation

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Mallet Finger

Mallet finger is a traumatic injury to the tip of an athlete's finger. It is also called *baseball finger* due to the high occurrence of this injury in the sport. The traumatic blow, typically caused by a ball impacting the tip of a finger, may result in permanent loss of distal finger extension if not treated promptly and appropriately.

Mechanism of Injury

As described above, a ball or object forcefully contacts the tip of an athlete's finger. The trauma results in a sharp movement of the distal interphalangeal (DIP) joint or the last joint of the finger from extension to flexion. This sharp movement results in a tearing of the extensor tendon on the dorsal (top) part of the finger (see Figure 1). The extensor tendon is very thin at this point of the finger, so it is easily damaged. If the resultant force is a slower blow, then an avulsion injury (chip fracture with the tendon intact) can occur. The athlete would exhibit swelling, bruising, or inability to extend the distal part of the finger. Typically, passive extension remains, and the athlete may think it is only a sprain.

Symptoms

The athlete may experience pain at the tip of the finger; however, the main symptom remains the inability to actively extend the distal portion of the finger. Blood may be present below the nail bed. If a patient notices blood under the nail bed, he or she should seek immediate medical attention as a detached nail bed signifies an open fracture.

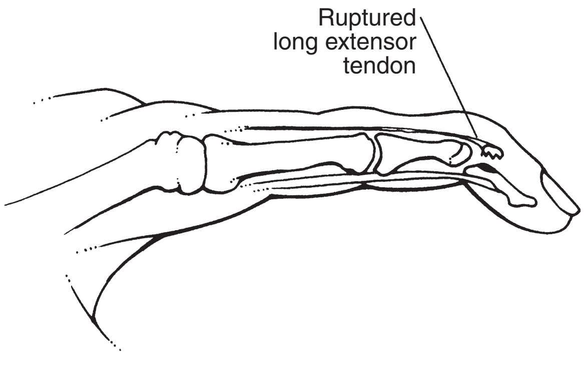

Figure 1 Mallet Finger

Notes: Mallet finger is a traumatic injury to the distal finger, resulting in tearing of the extensor tendon. Often a small portion of bone comes off, too, making it a tendon avulsion injury.

Diagnosis

A sports medicine physician will examine the finger for active and passive range of motion. In addition, palpation of the dorsal aspect of the distal finger may result in pain or a palpable defect (i.e., a hardened bump or divot). An X-ray of the finger may be taken to discern whether it is an isolated tendon injury or an avulsion injury. An avulsion injury signifies that a piece of the distal finger bone has become dislodged with the tendon.

Treatment

The majority of mallet finger injuries are treated nonoperatively. The key to healing remains early detection and compliance with the treatment. The patient should apply ice for the first 4 days after the injury to decrease the swelling. The patient needs to be splinted in full extension for 6 to 8 weeks at all times. Two types of splints exist. First, the sports medicine physician may use an aluminum splint. The aluminum splint is placed on the dorsal aspect of the finger past the DIP joint to incorporate the distal and middle phalanges. Athletic tape is used to affix the splint to the finger. The second type of splint is called a "stack" splint. The stack splint is plastic in nature and surrounds the middle and distal portions of the finger. The advantages of the stack splint include increased compliance secondary to comfort and ease of use. The splint affixes to the finger with tape and sits under the finger, as opposed to over it like the aluminum splint. (The aluminum splint can occasionally fall off due to the taping.) On follow-up visitation during the 6 weeks of splinting, a repeat X-ray may be taken. If the physician removes the splint during one of the follow-up visits, the finger should not be manipulated as this movement could reinjure the finger.

Six weeks following splinting, the physician discontinues the splint. The patient can then start a home exercise program for further strengthening the tendon. A home exercise program consists of five different exercises. First, passive range-of-motion exercises (flexing and extending the finger with the assistance of the opposite hand) afford improved range of motion of the distal portion of the finger. Second, making a fist and holding the position can improve both range of motion and strength. Third, the patient can pick up small objects such as coins, buttons, and so on, to improve dexterity and proprioception. Fourth, active distal finger extension (moving the injured finger up on its own) can slowly increase the range of motion. Fifth and foremost, the patient can improve grip strength with a grip ball. Again, these exercises should be performed *after* the 6 weeks of splinting and immobility.

Occasionally, nonsurgical treatment is ineffective. These cases typically involve large fractures attached to the tendon or those cases unresponsive to splinting. Surgery involves fixation of the fracture site followed by conservative treatment for the tendon.

Another reason why early treatment is essential is the potential development of a swan-neck deformity. Since the mallet finger results in tearing of the extensor tendon, lack of treatment places more pressure on the volar plate (the underside) of the proximal interphalangeal (PIP) joint, or the middle portion of the finger, to contract. This contracture can lead to a swan-neck deformity, in which the finger appears flexed distally and extended proximally. Once this deformity occurs, the chances of natural finger motion returning are unlikely.

Return to Sports

Typically, patients may return to noncontact sports immediately provided that they have been splinted and the splint can be maintained through the sport activity. For athletes who participate in contact sports, return to play is decided on a case-by-case basis. The sports medicine physician can be creative in maintaining a splint in full extension in a soccer goalie or linebacker. The splint would fit under the glove, and the finger could also be buddy taped for further immobilization. For sports with potential contact, such as baseball, return to play may be difficult as the athlete may have problems gripping the bat or throwing while splinted.

Douglas Comeau

See also Bracing; Hand and Finger Injuries; Hand and Finger Injuries, Surgery for

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Manual Medicine

Manual medicine is the art of using hands-on treatments and techniques to facilitate healing and tissue recovery. Use of such treatments has been documented for over 2,500 years. Manual medicine ranges from the mainstream (physical therapy, therapeutic massage, osteopathic and chiropractic manipulation) to the alternative (acupuncture, chakra testing). In the United States, the acceptance and use of manual medicine is growing steadily as evidence of its efficacy and safety accumulates. It is widely accepted and used in athletics, where manual medicine helps athletes recover faster and return to play quicker.

Athletics

The athletic population is well suited to enjoy the benefits of manual medicine treatments. Athletes stress their bodies and joints constantly during practice and competition, which inevitably leads to tissue breakdown and injuries both acute and chronic.

The body compensates by producing an inflammatory response, which also triggers muscle spasm acutely and scar tissue formation chronically. As these injuries accumulate, they lead to alterations in the motion and stability of joints and skeletal segments. Muscles lose flexibility, firing patterns change, and functional stability can decrease. The body then develops compensatory mechanisms to handle these changes, which can lead to further breakdown.

Traditional treatment of injuries may include rest, ice, compression, elevation, and the use of anti-inflammatory medications, usually resulting in the reduction of pain. The athlete then undergoes a period of rehabilitation focused on restoring range of motion, strength, and function. Manual medicine is used as an adjunct to facilitate quicker return to play.

History and Use

The history of manual medicine in the West can be traced back to the Greek physician Hippocrates (ca. 460 BCE), who advocated using massage as a method of treating patients. More recent developments in manual medicine started when the first osteopathic, chiropractic, and physical therapy schools were established during the late 1800s. Manual medicine techniques have continued to develop throughout the past two centuries.

Manual medicine encompasses a variety of therapies and cultures. In Western Europe, North America, and Australia, manual therapy is usually practiced by members of health care professions, including chiropractors, physiotherapists/physical therapists, osteopaths, physiatrists, and massage therapists. Recent surveys estimate that Americans make 192 million visits per year to chiropractors and 114 million to massage therapists. If you have seen one of these practitioners for your sports-related injury, the chances are that you had some type of manual medicine treatment.

Common practitioners of manual medicine include the following:

- *Physical therapists* provide services to patients to restore movement and regain function in injured areas of the musculoskeletal system. They are the main practitioners of rehabilitation in the United States and are an invaluable part of sports medicine teams. They work closely with physicians in developing treatment plans for managing injury and loss of function.
- *Osteopathic physicians* are fully licensed physicians in the United States and can evaluate, diagnose, and treat medical conditions. They are trained in the understanding that structure and function are related and that the body has inherent mechanisms to correct underlying dysfunction. Their practice scope is limited in European countries and Canada to just manual medicine.
- *Chiropractic physicians* are licensed to perform manual medicine techniques and are widely consulted for musculoskeletal injuries. Chiropractors believe that your spine and your health are fundamentally related and alterations in the spine can have negative effects on the musculoskeletal and nervous systems.
- *Massage therapists* have developed various styles and forms of massage over the past 25 years. They are an accepted part of an injury recovery program, particularly for those trying to maintain function while still competing. Therapeutic

massage is well researched, and practitioners need a high level of understanding of physiology and anatomy to become licensed in the United States.
- *Athletic trainers* are often the primary source of rehabilitation and treatment for athletes, often working with them on a day-to-day basis. Their skill set includes rehabilitation, massage, first aid, basic orthopedic evaluation, splinting, and taping. Many training programs have added manual medicine skills to the curriculum.

Techniques

The goal of most manual medicine techniques is to help restore normal body function and motion. Specific goals include the following:

- Realigning the vertebral spine
- Relaxing muscle spasm
- Improving joint range of motion
- Increasing blood and lymph circulation
- Reducing myofascial restrictions and scarring
- Improving muscle firing patterns

There are different types of manual medicine techniques that involve hands-on contact for diagnostic and therapeutic purposes. These techniques are on a continuum based on the amount of force used to perform them, including the following:

- *Soft tissue articulation and mobilization:* These procedures are applied to the musculature surrounding the spine or extremities and consist of a rhythmic linear stretching (mobilization), deep-pressure massage, and traction. The purpose is to loosen tension and relax tight muscles and connective tissue. Examples of soft tissue techniques include therapeutic massage, stretching, and myofascial release.
- *Lymphatic techniques:* These methods promote the circulation and drainage of lymphatic fluids. They are used to relieve swelling and improve circulation and healing response.
- *Indirect methods:* These techniques treat restrictions and dysfunctions by moving the joint away from the restrictive barrier and facilitating release through pressure, passive movement, and respiration. Some of these techniques are strain-counterstrain, Still's technique, and functional positional release.
- *Muscle-energy technique:* In this technique, the patient is directed to use his or her muscles against a counterforce applied by the practitioner, increasing the mobility of a particular joint or muscle.
- *Articulatory or thrusting maneuver:* Here, the practitioner applies a quick force to restore normal joint motion. This technique uses long- and short-lever systems. Often, you can hear a pop when the restriction is removed. As a result, symmetry and function are improved.

History and Physical Examination

The practitioner starts by taking a medical history, including the mechanism of injury, symptoms, location of pain, treatment to date, physical activities, past medical history, family history, and psychological factors that may delay recovery.

A physical examination is then completed, which includes scrutiny of general appearance, regional orthopedic and neurological examination, assessment of aberrant movement patterns, examination of related body parts, inspection of posture, palpation, and gait analysis. The athlete will invariably show changes in muscle texture, symmetry, and joint motion. Tender points on muscle or connective tissue are also common signs of injury or dysfunction.

For example, a basic rehabilitation strategy for ankle sprains is to reduce inflammation and swelling. This is done traditionally by using *r*est, *i*ce, *c*ompression, and *e*levation (the RICE method). Manual medicine treatments can facilitate this process by performing a mobilization technique that enhances venous and lymphatic drainage from the injured extremity. This can be followed by thrust maneuvers of the foot and knee to correct the restriction caused by the ankle sprain. Once the athlete's pain has improved, he or she can begin strengthening of the injured leg/ankle and work on improving balance. Guidelines for return to play include full range of motion in the injured ankle, no swelling, and return of ankle strength to 90% of the strength of the uninjured ankle. Manual medicine techniques often speed recovery, and the athlete is able to return to competition faster.

Conclusion

Manual medicine is a hands-on approach used to facilitate rehabilitation from an injury. Manual medicine techniques correct restrictions in the body so that the body can eventually heal itself and regain its function. The various techniques, including soft tissue mobilization, muscle energy, and thrust maneuvers, promote improvement in muscle and joint motion. This allows the athlete to recover more quickly and return to play sooner. When manual medicine is used in conjunction with traditional approaches to injury and pain, the result is better patient outcomes and increased patient satisfaction. Research studies have confirmed the therapeutic benefits of manual techniques in treating neck and back pain. Further studies are needed to determine the long-term benefits of manual medicine.

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See also Complementary Treatment; Physical and Occupational Therapist; Principles of Rehabilitation and Physical Therapy; Sports Massage Therapist

Further Readings

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Marathons, Injuries in

The marathon is a long-distance race that has boomed in world popularity since the early 1970s and is considered by many to be the ultimate challenge in physical endurance. The annual number of marathon finishes in the United States alone is nearly half a million a year. It was not until the 1970s that women became formally involved in the sport of marathon racing, and the distance was added to the Olympics in 1984. The expansion of marathon participation is due in large part to the number of women who have hit the roads, making up more than 40% of the race participants. While marathon participation has increased and the fastest runners have improved the world records for both sexes, the average popular marathon finish time has increased to 4.75 hours.

Minimum Criteria for Marathon Participation

Marathon training is rigorous, time-consuming, and certainly not for everyone. Nor is it to be taken lightly: Runners with underlying, but quiescent, coronary artery disease die of cardiovascular causes during marathon training and competition, and runners without a solid background of running and tissue toughening get injured during training and often do not make it to the starting line. Before embarking on the journey to complete the first marathon, it is prudent for a new runner to spend 2 to 4 years building up the volume of running in order to accommodate the rigors of marathon training. The preliminary running allows the muscles to strengthen and the tissues to "toughen" to meet the physical demands of the activity. There are programs that will take a "never-ever" runner to the level of marathon completion in a relatively short time, but the risks of soft tissue overuse injury and stress fracture are potentially greater than in a runner with several years of shorter-distance road running, who begins the marathon training program from a more seasoned platform.

From a cardiovascular perspective, a potential marathoner should be in good health with no known heart problems, have a clear family history (no early coronary artery disease and no unexplained sudden death, including during sleep, death by drowning, and single-car accidents), be a nonsmoker, and have a good cholesterol profile. A new marathon runner with one of the preceding conditions or risk factors, a male over age 40, or a female over age 50 should consult with a physician and consider an exercise stress test if there are risk factors for cardiovascular disease.

A lifelong running history usually produces a tested heart, but it does not guarantee that there is no risk from cardiovascular disease. Even runners who have completed several marathons have been shown to have high levels of coronary artery calcifications, beyond the expected levels. In a recent study of 108 male German marathon runners, 36% had coronary artery calcium scores >100, while only 22% of 216 men with similar heart disease risk factors who did not run at all had scores >100. In addition, there is at least one study that shows transient cardiac dysfunction and biochemical evidence of cardiac injury (release of cardiac stress markers) in healthy amateur marathoners, with the cardiac stress profile being greater in runners who train <35 miles (mi)/week (1 mi = 1.69 kilometers [km]) than in runners who train >45 mi/week. This should not discourage runners from undertaking the marathon challenge as there are no data to show that the changes noted were either detrimental to the runners' health or accelerated by participation in the marathon, but it does emphasize the need for adequate training and attention to cardiac risk factors.

Bassler's hypothesis early in the running boom suggested that a marathon runner could not get coronary artery disease and die of a heart attack. This was disproven in the Boston Marathon around the time of the statement, and the risk of sudden cardiac arrest (SCA) and sudden cardiac death (SCD) is real and has been documented in the range of 1 in 75,000 finishers. The deaths are mostly of men over age 40 with coronary artery disease. There have been deaths in every major marathon, including New York, Boston, London, Berlin, Chicago, Marine Corps, and Twin Cities. A healthy lifestyle and a keen appreciation of the symptoms of cardiovascular disease will do the most to decrease SCD in marathon runners.

To condition both the heart and the running-related musculoskeletal system, it is prudent for a potential marathon participant to have a running history of 2 to 4 years, with a training log showing 15 to 20 mi/week, some 5- to 10-km road racing experience, and at least one 10- to 15-mi race prior to ramping up the mileage for the marathon race. Training should gradually build up to 30 to 40 mi/week and culminate in several weeks of consistent running at >45 mi/week leading into the marathon. Most training programs will suggest that the runner complete at least two 20-mi runs 3 and 2 weeks prior to the race. A training program should include rest—typically 1 day/week with no exercise, with hard and easy workouts alternating on the other days of the week.

Marathon participation also takes a lot of "heart." Mental preparation is important to complete the race and must be accompanied by the "will to finish"; however, knowing when to quit if symptoms arise during the race may be the key to avoiding cardiac arrest, heat stroke, and other race-related problems.

Collapse During and After a Marathon

There are five usual causes of collapse during and after a marathon race: (1) SCA and SCD, (2) fluid balance issues including exertional hyponatremia and dehydration, (3) hyperthermia and exertional heat stroke, (4) hypothermia, and (5) exercise-associated collapse. Some of these conditions are self-limited and very common, and some can be life threatening although relatively rare.

SCA and SCD associated with marathon racing are relatively rare and most common in men. There has been a great effort on the part of race medical teams to develop rapid response teams, and a recent study showed the SCD rate in two major marathons to be 1 in 220,000 finishers, presumably due to rapid response and application of a defibrillator. An SCA during a marathon is usually an unexpected collapse, most likely due to coronary artery soft plaque rupture producing sudden occlusion of the heart artery. Unlike the large, calcified plaques that produce angina heart pain, the smaller, soft plaque does not occlude the artery blood flow and induce the growth of collateral blood vessels to protect the heart muscle from decreased or stopped blood flow. The abrupt occlusion from a soft plaque rupture produces an arrhythmia, with an unprotected collapse to the ground, often resulting in facial lacerations and fractures in addition to a stopped heart. The more rapid the response with an automatic external defibrillator, the more likely the runner will survive.

Fluid Considerations

Most marathons make fluids available along the course at 2- to 3-mi intervals, and the mega-marathons, such as Chicago, New York, and London, have fluid stations every mile to improve access in the crowded conditions. Severe dehydration is relatively rare in marathon racing, but mild to moderate dehydration occurs relatively often, is usually well tolerated, and is easily treated with oral fluid replacement. Replacing fluid during the race has the advantages of improving performance and maintaining blood volume. Keeping the blood volume near normal by replacing most sweat losses allows the most efficient transfer of muscle-generated heat to the body surface and keeps the vascular system flowing for exchange of oxygen and nutrients.

The problem associated with ingesting too much fluid is called exercise-associated hyponatremia (EAH), defined as a serum sodium (Na^+) level of <135 millimoles per liter. *Hyponatremia* can present with life-threatening cerebral and pulmonary edema and requires immediate medical attention. It is caused by too much fluid intake combined with poor kidney water clearance and is usually found in slow runners who are on course for >4 hours and ingest too much water or sports drink compared with the amount of fluid lost in sweat and urine. Affected runners tend to gain rather than lose body weight during the race, although in some cases runners maintain weight. Serum sodium losses in sweat make a minimal contribution to hyponatremia in "normal" marathon runners.

Prerace, race, and postrace hydration recommendations suggest that keeping urine pale yellow, like the color of lemonade; replacing no more than sweat losses during the race with an individualized fluid intake plan; and planning to lose a pound or two during the marathon race is the safest approach to fluid management. Lacking a fluid replacement plan, "drink when thirsty," to avoid too much fluid, but "do not ignore thirst," to avoid dehydration, is a reasonably safe option. Sports drinks may delay onset but do not prevent dilutional hyponatremia, and it is not safe to assume that having a sports drink will protect a runner from overhydration. Postrace ingestion of an initial salty drink, such as chicken broth, will help the body retain water in the rehydration process.

Recognition of hyponatremia is difficult in the early stages, when nonspecific symptoms and signs, such as lightheadedness, dizziness, headache, and nausea, may be confused with other race-related problems. As symptoms and signs progress, vomiting, dyspnea, muscle cramps, confusion, and "puffiness" may help focus the diagnosis. Late signs and symptoms of cerebral edema (prolonged seizure and obtundation), pulmonary edema (respiratory distress), and shock (ashen, gray appearance) are life threatening. The problem may be asymptomatic or minimally symptomatic for several hours, may present with "flu"-like symptoms later in the hotel or at home, and may present with muscle cramping or severe headache. Hyponatremia can deteriorate rapidly, progressing to seizure, respiratory distress, and coma due to worsening pulmonary and cerebral edema in short order.

If suspected, the medical staff at the marathon site or in the emergency room will check the serum sodium level, hematocrit, and blood urea nitrogen (BUN) to make the diagnosis. The treatment of relatively asymptomatic hyponatremia is simple: The medical team will observe the runner closely and allow natural diuresis to remove excess water via urination. Some medical teams will administer oral hypertonic solutions, such as four bouillon cubes in 4 ounces (113.65 milliliters [ml]) of water to draw water into the gut and relieve the water overload. If symptomatic, especially with encephalopathy from brain-related changes, the medical team will administer 100 ml of 3% saline intravenously over 10 minutes and repeat this until the sodium level normalizes or symptoms abate. Some medical teams choose to treat all cases in the emergency room, but that protocol has the potential to delay treatment.

Exertional heat stroke (EHS) occurs when the body temperature rises above the critical tissue levels that affect organ function, as a result of muscle heat generated by the work of running combined with inadequate heat loss usually due to exercising in hot, humid conditions. The usual definition of EHS is an elevated core body temperature >104 ºF associated with central nervous system (CNS) symptoms and other organ dysfunction (caused by heat-induced malfunction of cells and organ tissues). This is most often a problem in "short" races that are run at a faster pace than the marathon distance. The pace of the last 5 to 10 km often determines the risk of heat stroke in the marathon.

The risk is low in marathons run in cool conditions with race temperatures in the 40 to 50 ºF range, but as temperature and humidity rise, the incidence of heat stroke also rises to >1 per 1,000, even when the start temperature is a low 70 ºF, as at the Twin Cities Marathon. Heat and humidity associated with marathon-related heat stroke are often unexpectedly high for the race, and runners are not acclimatized to such conditions.

Rectal temperature measurement is required to detect heat stroke because more convenient sites such as the ear canal, tympanic membrane, forehead

(TAT), oral cavity, and axilla are in the shell and will be falsely low—missing the diagnosis and delaying life-saving cooling. Runners with heat stroke often present with "collapse," either to the ground or requiring the assistance of others to remain upright. Symptoms include fatigue, impaired judgment, weakness, flushing, chills, hyperventilation, dizziness, and intense thirst (in some). CNS depression is the most easily recognized marker of exertional heat stroke and may be simply demonstrated as bizarre behavior. Some heat stroke victims have a semilucid interval with subtle personality changes that may seem normal to a "stranger." Memory loss is common, starting at the time of critical body temperature elevation. The loss of lower limb function results in collapse and can proceed to delirium, stupor, and coma. Skin color is ashen in appearance due to circulatory collapse, and the skin is usually sweaty, wet, and even cool to the touch. Dry and hot skin is rare early in collapse from heat stroke, signifying loss of hypothalamic control of the body cooling system.

Once the diagnosis of exertional heat stroke is made, the goal is to bring the core temperature down to normal as quickly as possible. The most rapid cooling method is to place the runner in a tub of ice water to cool the body to the normal temperature range in 20 to 40 minutes. Another commonly used technique is to wrap the body in a sheet or several towels that have been dipped in ice water and then change them quickly to remove heat from the body. In an emergency situation, anything that will help remove body heat is helpful, including shade; air conditioning; ice packs to the neck, axilla, and groin; wet, cool towels; soaking with a garden hose, or using fans. However, none of these methods is as effective as immersion in ice water. If cooling is successful, the runner is either evaluated in a local emergency facility or allowed to leave the medical area with follow-up instructions.

Exercise-Associated Collapse

Exercise associated collapse is a common problem following the marathon that excludes orthopedic injuries and the problems previously outlined. A runner completing the race often requires some intervention for exhaustion and inability to continue in an upright walking posture. The reasons for this type of collapse are not fully understood but probably have to do with loss of vasovagal tone and loss of venous blood return when the leg muscles stop contracting regularly (loss of the muscle pump when running is stopped). Most runners recover rapidly by lying down and elevating the legs. In the finish area, many runners assume this position as part of their postrace recovery without reporting to the medical tent.

Marathon Race Medical Plans

The medical team for each marathon prepares protocols and equipment in advance to respond to the common, self-limited problems on the course and at the finish line, leaving the community emergency facilities open to the general public and for the rare life-threatening marathon-related problems.

The race medical team provides competitor education regarding the risks of marathon racing and the safety measures required to reduce individual risk, including much of the material discussed in the preceding section. The type and location of medical assistance along the course and at the finish should be explained in the prerace materials, along with how to identify the medical team volunteers. Often the medical team will have a standard color T shirt, jacket, or vest to make it easy to locate assistance during and after the race.

Preparticipation screening is usually not required for mass-participation marathons and is left to each individual to determine under the advice of a personal physician. Even prescreened athletes have suffered SCA, heat stroke, and hyponatremia in the course of marathon participation. Many marathons have an impaired competitor policy that allows medical evaluation without disqualification. This allows the medical staff to establish criteria for runners to continue in the event, usually including the following: The individual (a) is oriented to person, place, and time; (b) is making straight-line progress toward the finish; (c) has a good competitive posture; and (d) has a clinically fit appearance. Runners will be disqualified for any problem that appears to risk life or health or requires intravenous (IV) fluids.

Hazardous conditions that increase the risk to runner and volunteer safety during the marathon, including heat, cold, traction, windchill, and lightning, and may lead to cancellation of the event are usually published in advance of the race. Conditions that overload local emergency facilities also pose a threat to community health if the medical system is "clogged" with runners and community members cannot access care.

There are generally two types of aid stations for medical care: (1) major stations, which offer full race medical care, usually located at the finish area and in sites that historically have a high medical volume along the course and (2) minor stations, which offer comfort care and first aid. Many races have mobile aid, with teams in vans, on golf carts, and on bicycles carrying automatic external defibrillators for rapid response to possible SCA victims. Severely ill competitors along the course and at the finish area are usually transported by ambulance to the nearest hospital.

Competitor safety is always the primary goal of the race and the medical team. The medical plan should include strategies to prevent injuries, stop the progression of injuries, and relieve emergency rooms of excess admissions on the race day.

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See also Foot Injuries; Heat Illness; Medical Management of an Athletic Event; Running Injuries; Sports Drinks

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Marfan Syndrome

Marfan syndrome is an inherited problem of connective or soft tissues. It affects many parts of the body. This entry reviews the basic findings on Marfan syndrome and provides general treatment guidelines for some features.

Cause

Marfan syndrome is caused by a genetic mutation or change in the fibrillin gene. It is inherited in an autosomal-dominant fashion. This means that if a parent has the syndrome, each of the children has a 50% chance of having the syndrome. Most (about 75%) cases are inherited from affected parents, but some (about 25%) occur from chance mutations in the gene. The incidence is about 1 in every 10,000 people in the United States, with roughly 200,000 people living with this syndrome. Tissues in the body that contain fibrillin include the eye lenses, ligaments (which join bones together), and blood vessels. As a result, these areas are the most affected by this syndrome.

Features

Musculoskeletal/Muscles and Bones

People with Marfan syndrome are tall with long thin limbs and fingers, which is called arachnodactyly, or spider digits. Scoliosis or a curvature in the spine is commonly seen in up to 70% of patients. Chest wall or pectus deformities also can be seen. Another feature is hyperflexibility, which can cause extremely flat feet and dislocated joints. In the photo, a patient with Marfan syndrome is seen from the back. The features of long thin limbs and a spine curvature are visible. Other musculoskeletal problems include deep hip sockets (*protrusio acetabulae*) and abnormal growth of the lining around the spinal cord (*dural ectasia*), which can cause back pain.

(a) Marfan patient with spinal curvature and long thin limbs (b) Marfan patient bending forward showing rib hump from spinal curve

Source: Children's Orthopaedic Surgery Foundation.

Ocular/Eyes

People with Marfan syndrome often have poor vision and need glasses from a young age. A complete dislocation of the eye lens can happen.

Cardiovascular/Heart

The most serious effect of Marfan syndrome is on the blood vessels. Because the fibrillin in them is weak, they can stretch out and even rupture. The main artery that carries blood from the heart to the body, the aorta, is most at risk. It can stretch out and dilate into a balloon-like pouch (called an aneurysm) or even suddenly tear (called a dissection). Also, the valves in the heart may be too floppy to function properly. Some patients with Marfan syndrome have died suddenly from these problems. There are notable cases of tall, thin basketball players, in particular, who have died suddenly from aortic ruptures caused by undiagnosed Marfan syndrome.

Skin

Stretch marks are common and usually not a cause for concern.

Pulmonary/Lungs

In adult life, lung problems such as early emphysema are common. If severe spinal curvature or chest wall deformities are present, the lung capacity may be compromised by them. Spontaneous lung rupture (pneumothorax) can occur.

Diagnosis

Although the gene causing Marfan syndrome has been found, many different changes in it can cause the syndrome, making genetic blood tests imprecise currently. Thus, usually Marfan syndrome is diagnosed clinically after the exam by an experienced team of doctors. There are different criteria used to judge whether a patient truly has the syndrome rather than simply a few features of it. For example, few people with a spinal curvature and glasses have Marfan syndrome. The National Marfan Foundation website (http://www.marfan.org) has excellent information reviewing the diagnostic criteria that are used. Often a patient who is thought to have Marfan syndrome will see several different doctors to monitor all of the potential problems that may occur. An orthopedist will review the musculoskeletal problems. X-rays are often ordered. Before any spine surgery or in the case of back pain, magnetic resonance imaging (MRI) may be needed to assess variations from normal anatomy. An ophthalmologist will evaluate the eyes. A cardiologist will evaluate the heart; usually heart ultrasound scans called echocardiograms are used to monitor whether the aorta and heart are the proper size and working well. Computed tomography (CT) and MRI scans may be needed too. A geneticist often makes the final determination as to whether a true case of Marfan syndrome is present. Family history is very important as is counseling for patients with Marfan syndrome about their risk (50%) of passing the syndrome on to their children.

Treatment

Marfan syndrome is heterogeneous, meaning that not all patients have the same problems. Thus, treatment focuses on what problems exist in that particular person. Vision problems are treated with glasses and, occasionally, corrective surgery. The heart and aorta are monitored with echocardiogram ultrasounds and routine checkups. Some medications are available that can slow the heart and the progression of the dilation. If significant heart problems are found, strenuous physical activity must be avoided. If the dilation of the heart and/or aorta becomes severe, open heart surgery may be needed to replace the weakened areas. Some musculoskeletal problems such as flat feet may be braced. For severe deformities in the chest, spine, or limbs, surgical correction can be performed. With proper medical treatment and some lifestyle adjustments, people with Marfan syndrome can lead productive, happy lives and live as long as unaffected people. However, undiagnosed Marfan syndrome can lead to sudden death. Participation in sports depends on the severity of Marfan syndrome. Thus, some people may be able to play sports, though low-impact sports such as swimming are generally easier for their bodies. If there is heart involvement, contact sports such as basketball and football are strictly prohibited.

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See also Athlete's Heart Syndrome; Sudden Cardiac Death

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Medial Apophysitis of the Elbow

Medial apophysitis of the elbow is an overuse injury to the medial epicondyle growth plate. It is most commonly seen in young pitchers, generally between the ages of 9 and 14. It is sometimes called Little League elbow, but other authors use *Little League elbow* to refer to a constellation of injuries commonly seen in the skeletally immature elbow, including medial apophysitis, osteochondritis of the capitellum, overgrowth of the radial head, and premature closure of the proximal radial physis.

Anatomy

An apophysis is a bony protuberance near a physis or growth plate and serves as the insertion site of major tendons and ligaments. A physis, consisting of cartilage and new bone, is where bones actively grow during development, and as a bone matures, the physis will fuse and become all bone. However, while the physis is still open, it is weaker than all the surrounding tissues, including the formed bone, ligaments, tendons, and muscles. Therefore, *apophysitis* results when stress is applied to an apophysis.

The medial ossification center appears around the age of 5 and generally closes by age 15, forming the medial epicondyle. The medial epicondyle is the attachment site for both the flexor-pronator mass and the ulnar collateral ligament (UCL). The combination of repetitive contraction of the wrist flexors and elbow pronators and the valgus stress from the throwing motion puts the medial apophysis at increased risk for injury.

Epidemiology

The increase in organized sports participation has resulted in a similar increase in injuries among pediatric athletes. Increased specialization at a young age, year-round training, and increased intensity of training at an early age also contribute.

Surveys from Little League baseball have repeatedly shown that the elbow is the most commonly injured joint in youth baseball, with the annual incidence of elbow pain in 9- to 12-year-old players between 20% and 40%. Medial apophysitis is the most common cause of medial elbow pain in this age-group. While it is most commonly seen in pitchers, it can also be seen in other positions in baseball, as well as other overhead sports such as tennis and the quarterback position in football.

Causes

The overhead throwing motion results in valgus stress to the elbow, especially during the cocking and early acceleration phases of throwing. When this stress is repetitive, it can lead to injury to the medial structures of the elbow: medial apophysitis in the skeletally immature and UCL injury in the skeletally mature. Training errors are another common contributing factor. Common errors include sudden changes in the intensity and duration of throwing, too much throwing, inadequate preseason conditioning, poor throwing mechanics, and throwing breaking pitches at too early an age. Proper throwing mechanics depend on correct transfer of forces from the legs, through the torso, and into the arm, so strength and flexibility imbalances and injuries to other parts of the body can also lead to injuries to the elbow. Curveballs and sliders put much more stress on the elbow than fastball and change-up pitches, and they have been associated with a higher risk of medial elbow injuries.

Symptoms and Signs

The classic complaints of medial apophysitis are chronic medial elbow pain, decreased throwing velocity or distance, and decreased throwing effectiveness. Pain is generally worse during cocking and acceleration. Pain will have a gradual onset; if the patient complains of a sudden onset of pain while pitching, a medial epicondyle avulsion should be considered. Lateral pain may suggest associated injuries, such as osteochondritis of the capitellum and overgrowth of the radial head. When obtaining a history, the throwing history is very important. Ask questions about pitch counts, the types of pitches thrown, the number of practices and games per week, and recent changes in pitch types or counts.

Examination will show point tenderness over the medial epicondyle. If the patient has associated injuries to the capitellum and radial head, there may also be tenderness laterally and over the radial head. Medial swelling is common. Most patients will have full range of motion, but some may have a flexion contracture. There will usually be pain with resisted elbow pronation and wrist flexion but no pain with resisted elbow flexion or extension. On valgus stress testing, the patient will have pain but no laxity. If there is any laxity, injury to the UCL or medial epicondyle avulsion should be considered.

Diagnosis

If medial apophysitis is suspected, plain X-rays of the affected and opposite elbow should be done to detect fractures, loose bodies, and growth plate abnormalities. It is important to compare the width of the growth plate with the uninjured side. Most patients will have normal radiographs, but subtle differences in the width of the physis may be seen. If the difference is greater than 3 millimeters, the patient should be referred to a sports medicine orthopedic surgeon for consultation. Medial epicondyle fragmentation or hypertrophy is also commonly seen, but does not change the treatment. Magnetic resonance imaging (MRI) and computed tomography (CT) scans are generally not needed for medial apophysitis, but if injuries to the capitellum, radius, or UCL are suspected, an MRI scan may be considered.

When a patient presents with medial elbow pain with throwing, the other diagnoses that should be considered are avulsion fracture of the medial epicondyle and UCL sprains. Both of these will occur in patients with a history of repetitive valgus overload from throwing. Medial epicondyle avulsions present in the same age-group as medial apophysitis, but patients are more likely to complain of a sudden onset of pain while throwing, sometimes with a pop. It is not uncommon, however, for them to have a history of chronic pain before the acute onset. This is thought to be caused by preexisting medial apophysitis. There generally is more swelling than is seen in medial apophysitis; there is tenderness over the medial epicondyle, and often there is laxity with valgus stress testing. UCL sprains are more likely to occur in older throwers with fused growth plates. They may have an acute or chronic history of medial elbow pain, sometimes with a history of a pop as well. On exam, tenderness is more localized to the UCL than to the medial epicondyle. They will also have pain with valgus stress testing, with or without laxity. If either of these diagnoses is suspected, referral to a sports medicine specialist is recommended.

Treatment

The most important part of initial care for the patient with medial apophysitis is rest from throwing. Generally, 4 to 6 weeks of complete rest from any valgus stress is recommended. Ice and nonsteroidal anti-inflammatory drugs may be helpful for pain control. Occasionally, if pain is severe, immobilization for 7 to 10 days may be necessary. Initial physical therapy is focused on treating the flexion contracture, if present, and general strengthening and flexibility for the entire body.

After the rest period, if the patient is asymptomatic and has no tenderness or pain with valgus stress, a progressive return-to-throwing program can be started. The first phase is long toss, gradually increasing the velocity and then on to noncompetitive pitching, focusing on good throwing mechanics. Any return of pain will require rest for at least 2 to 3 days until the symptoms subside and then restarting at a lower level of intensity. This program should take 6 to 8 weeks, with the average time of return to pitching being 3 months from diagnosis. If these recommendations are followed, most patients will respond favorably.

Prevention

Prevention is the most important way to deal with this problem. The USA Baseball Medical and Safety Advisory Committee has made a number of recommendations to help prevent elbow injuries in young baseball players. The number of pitches thrown in practices and games and the number of innings pitched per week and season should be closely monitored. The committee has established pitch counts that vary by age and competitive level. Athletes who pitch in more than one league (e.g., on a travelling or all-star team) should follow the same guidelines, totaling the pitches for both leagues, even though each league will only monitor the pitches in its league. They have also recommended the types of pitches that should be taught at the different ages: fastball, 8; change-up, 10; curveball, 14; knuckleball, 15; slider, 16; forkball, 16; splitter, 16; and screwball, 17. Prevention can also be accomplished by educating parents, coaches, and players about the causes and symptoms of medial apophysitis. Pitchers should be taught that at the first sign of elbow pain, they should stop pitching and seek medical evaluation. Emphasis should be placed on proper throwing techniques and proper training. Overall conditioning and a good preseason program should be stressed. Pitchers should throw at the most 9 months of the year and should have at least 3 months of rest from all overhead activities annually. By following these recommendations, most cases of medial apophysitis can be prevented.

Michael Stump

See also Little League Elbow; Medial Epicondyle Avulsion Fractures of the Elbow

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Medial Epicondyle Avulsion Fractures of the Elbow

Elbow fractures occur commonly in contact sports and constitute 10% of all fractures in children. Mechanisms of injury are usually direct trauma or a strong directional force on the elbow. In adults, it is rare to have an isolated epicondylar fracture. In children, medial epicondylar fractures are the third most common elbow fracture, after supracondylar and lateral condylar fractures. Elbow fractures and dislocations are serious injuries that can result in functional instability due to malalignment, malunion, nonunion, or concurrent soft tissue injury to stabilizing structures. Any young athlete who complains of medial elbow pain must have a thorough evaluation for injury to the growth plates or ossification centers of the elbow, with special attention to the medial epicondyle.

Anatomy and Clinical Evaluation

The elbow is one of the most complex joints in the body, consisting of three articulations: ulnotrochlear, radiocapitellar, and proximal radioulnar. The elbow is extremely congruent and stable due to the specific pattern in which the bones contact and conform to each other. Due to this configuration, anatomic alignment must be restored or maintained to decrease or minimize the functional disabilities resulting from injury. Common complications include decreased range of motion (ROM), structural instability, arthritis, nerve palsies, weakness, and heterotopic ossification. Radiographic evaluation of the pediatric elbow is particularly challenging due to the development and appearance of the six secondary ossification centers of the elbow and the relatively subtle appearance of some serious injuries. These ossification centers, or apophyses, can be remembered by the mnemonic CRITOE (*c*apitellum, *r*adius, "*i*nternal" [medial] epicondyle, *t*rochlea, *o*lecranon, "*e*xternal" [lateral] epicondyle). The ossification centers appear in order approximately every 2 years, starting from age 2 through age 12. The apophyses slowly close by ossification as the elbow matures and will be fully closed by approximately age 16. It is prior to the complete closure and ossification of the medial epicondyle that the vast majority of medial epicondyle fractures occur. The distal humeral epicondyles serve as attachment sites for the forearm flexor (medial epicondyle) and extensor (lateral epicondyle) muscle groups, the functions of which play a role in injury patterns.

Mechanism of Injury

The most common mechanism of injury to the medial epicondyle is repetitive valgus overload to the medial elbow. The stress to the flexor-pronator muscle-tendon group and/or the ulnar collateral ligament (UCL) results in a widening or separation of the medial epicondyle. This avulsion fracture can occur in the setting of an acute trauma as well. The medial epicondyle can also be injured during a traumatic elbow dislocation and become entrapped in the joint, often during a spontaneous ulnohumeral joint reduction.

Physical Examination

Physical examination includes inspection for swelling or deformities. Palpation should reveal localized tenderness and/or prominence of the medial epicondyle. Normal ROM is elbow flexion/extension 0° to 150° and forearm pronation and supination 90° in each direction. The UCL is an important stabilizer of the elbow. Multiple techniques exist for performing a valgus stress test on the medial elbow. These tests are often positive for reproducing pain as well as demonstrating signs of associated instability. Valgus stress testing at 70° to 90°, the moving valgus stress test, and the milk test are all described techniques. Any perceived laxity should be compared with the contralateral side and reevaluated at 0° of extension. It is sometimes difficult to distinguish ligamentous instability from that associated with a true medial epicondylar fracture; therefore, radiographs are essential as part of the initial evaluation. A complete neurovascular examination must be performed as associated neurovascular injuries can occur.

Imaging Studies

Standard anteroposterior (AP), oblique, and lateral views of the elbow should be sufficient to diagnose most elbow fractures. The lateral radiograph is helpful to evaluate for hemarthrosis and bony alignment. Comparison views are particularly helpful in evaluating the pediatric elbow for fractures due to the presence of the six secondary ossification centers previously described. Valgus stress views may be obtained, but they often fail to demonstrate the gross laxity detectable on physical examination. Epicondylar displacement may be seen on either the AP or the lateral view. The finding of 3 to 5 millimeters of medial epicondylar displacement is clinically significant and may serve as an indication for surgical fixation of a medial epicondylar fracture.

Advanced imaging techniques such as computed tomography may identify intraarticular fragments and assess the congruity of the articular surfaces when internal fixation is being considered. Magnetic resonance imaging (MRI) and/or MR arthrography is the most sensitive and specific imaging study to reveal injury to the medial (ulnar) collateral ligament, in addition to facilitating the identification of lateral instability, osteochondritis desiccans, intraarticular cartilaginous loose bodies, and physeal maturity. Increased signal at the medial epiphysis on an MRI scan in the absence of widening or displacement in a skeletally immature elbow indicates chronic medial injury consistent with valgus overload syndrome.

Treatment

Nonoperative treatment involves immobilization, usually a long arm cast for 3 to 4 weeks, to allow the medial epicondyle fracture to heal and prevent ongoing valgus stress to the elbow. Operative treatment may involve arthroscopic evaluation for concurrent instability, in addition to screw fixation of the medial epicondylar fracture fragment.

Rehabilitation

Rehabilitation of the injured elbow is essential to restore strength and stability whether the injury is treated operatively or nonoperatively. Usually, rehabilitation begins 4 to 6 weeks following immobilization and requires a progressive program of ROM, strength, and multiplanar exercise such as throwing so long as the activities are painfree. Even in cases of isolated medial epicondylar fractures not associated with instability, the elbow joint requires monitoring for recurrence of medial elbow pain and signs of complications such as stiffness, posteromedial osteophyte formation, ulnar neuritis/neuropathy, soft tissue/synovial hypertrophy or signs of impingement such as pain, locking, crepitus, and/or loss of extension. Serial radiographs as well as frequent physical examinations are important in the long-term treatment and monitoring of patients with medial epicondylar fractures.

Special Populations

Medial epicondylar fractures and, in general, valgus overload syndrome occur most commonly in young baseball players. As a result, much research has been conducted to identify the key risk factors for injury to the medial elbow. Pitch count limitations and proper pitch mechanics as well as general core strength and conditioning have been found to help prevent injury. The USA Baseball Medical and Safety Advisory Committee has made recommendations for guidance on appropriate pitch types and counts, which range from approximately 50 pitches per game for 10-year-olds to 100 to 110 per game for late high school–age and college-age pitchers, with season maximums of approximately 3,000 per year for young pitchers. The latest recommendations are available at http://www.usabaseball.com. Other general recommendations include not competing for more than 9 months/year, avoiding all overhead activities during the 3 months of rest, not participating in any after-game pitching practice, and playing in only one league per season. As noted, once removed, a pitcher should never return in the same game. Emphasis should be placed on year-round conditioning to promote endurance, core strength, neuromuscular control, and proper throwing mechanics. In conclusion, medial epicondylar fractures, particularly when associated with valgus overload and repetitive microtrauma, are potentially preventable injuries in athletes. When injury does occur, early intervention and proper treatment can minimize the risks of permanent injury or long term sequelae. Every athlete who experiences medial elbow pain, particularly with throwing or other overhead activities, should be referred to a sports medicine or orthopedic specialist immediately.

Holly J. Benjamin

See also Elbow and Forearm Injuries; Elbow Fractures; Little League Elbow

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Medial Tibial Stress Syndrome

Medial tibial stress syndrome (MTSS) is a painful exertional condition of the lower leg that is related to exercise, specifically running. The incidence is estimated to be between 13% and 25% among active individuals, making it the most common cause of overuse injuries in runners. Many people still refer to this as "shin splints." Although running athletes most frequently present with signs and symptoms consistent with MTSS, it is not uncommon in jumping athletes.

Definition

Pain from MTSS usually occurs at the posteromedial margin of the tibia, the junction of the posterior tibialis tendon and muscle, and the gastrocnemius-soleus complex. MTSS is often confused with a tibial stress fracture or chronic exertional compartment syndrome. Pain usually occurs with running and repetitive jumping, but the athlete can usually complete the activity. Pain occurs along a broader region of the tibia, causing tenderness along a quarter or a third of the tibial shaft length. It usually improves with rest and localized treatment, but the symptoms can linger if the underlying cause is not corrected.

MTSS is thought to be related to tibial stress reactions, periostitis (inflammation of the bone surface), or tendinopathy and may be on a continuum of stress injuries to the bone. Recent high-resolution computed tomography scan studies showed that areas of the tibia affected by MTSS had lower bone mineral density in athletes than in nonathletes and athletes without MTSS, suggesting a bony reaction. One study supports inflammation of the periosteum from excessive muscle traction on the tibia as the cause of MTSS.

Causative Factors

The intrinsic and extrinsic factors related to MTSS are listed in Table 1.

Table 1 Intrinsic and Extrinsic Factors Related to Medial Tibial Stress Syndrome

Intrinsic	*Extrinsic*
Runner's build	Running surface
Bone structure and alignment	Running shoe deficiency
Gender	Changes in training program

Source: Plisky MS, Rauh MJ, Heiderscheit B, Underwood FB, Tank RT. Medial tibial stress syndrome in high school cross-country runners: incidence and risk factors. *J Orthop Sports Phys Ther*. 2007;37(2):40–47.

The most controllable factor in medial tibial stress syndrome is a *sudden change in training*. Different shoes, a different running surface, a sudden increase in mileage or intensity, or suddenly starting running after being sedentary are factors that should be considered in any case of MTSS.

Excessive pronation of the foot is associated with MTSS, likely due to the torque of the tibia generated by the pronation, causing shearing forces from the lower leg muscles along the tibial shaft. Navicular drop, or the collapsing of the medial arch, has been thought of as a cause, but evidence is not conclusive. Loss of medial longitudinal arch integrity can increase instability as the foot plants and pronates, and it should be assessed in suspected cases of MTSS.

Gender studies differ in their conclusions with respect to MTSS. One study showed that men with MTSS have significantly smaller tibial cross-sectional dimensions than their uninjured exercising counterparts and the sedentary controls. A study by J. E. Bennet et al., published in the *Journal of Orthopaedic and Sports Physical Therapy* in 2001, found that high school women were more likely to develop MTSS than their male counterparts. In a 2007 study published in the *Journal of Orthopaedic and Sports Physical Therapy*, M. S. Plisky and associates found that there was an increase in MTSS in women as well, but when controlled for orthotic usage, this finding was no longer statistically significant. However, those who used orthotics were four times more likely to have previously had symptoms consistent with MTSS. Other researchers speculate that women are more likely to report a problem than their male counterparts.

Shoe wear should be routinely evaluated by the runner. Shoe integrity breaks down as mileage of the shoe increases, and its ability to absorb impact and stabilize foot motion decreases. A prevailing theory in running was that shoes have about 300 to 400 miles (mi; 1 mi = 1.69 kilometers) in them before you need to change them. That has been amended recently, as people have different wear patterns and loads. One person's shoe may be in great shape at 400 mi of wear, while another may be broken down at 200 mi. Mileage is a good guide for assessing shoe wear, but runners and their shoes should be evaluated independently.

Higher body mass index (BMI) is linked to MTSS due to the amount of stress loaded onto the tibia from above the tibia, while harder training surfaces increase the stress loaded on the tibia from below. So running in the street may be less desirable than running on a grassy field or an asphalt track.

Treatment

Treatment of MTSS includes relative rest, physical rehabilitation, orthotics, and manual medicine techniques, with a gradual return to activity. Rest is designed to allow recuperation and recovery of the lower leg, so rest can be just from the offending activity. Athletes with MTSS can run on a softer surface, run less often, or run in a swimming pool. Sometimes, no running is allowed, but bicycling or elliptical machine training is permitted; more severe cases require complete rest and non–weight bearing. After the symptoms resolve, return to activity should be gradual and progressive. With an acute onset of pain, ice or cold compresses should be used, but for no more than 20 minutes at a time. After 3 days, heat can be applied when alternated with ice.

Rehabilitation should focus first on core stabilization and strengthening. Rehab exercises should strengthen and lengthen the gastrocnemius-soleus muscle complex and the tibialis anterior and posterior muscles. The running stance should be evaluated and treated. Medial longitudinal arch deformations should have added support. Additional interventions may include ultrasound, phonophoresis, and electrical stimulation in the skeletally mature. Addressing lower leg tender points with manual therapy can be helpful in relaxing the myofascial connections and allows for a better response to rehabilitation. In some instances, cortisone injections are also useful for soft tissue injuries.

Rarely does MTSS require surgical treatment. There is no procedure specific for MTSS, but surgery may be indicated for structural issues that lead to biomechanical running flaws, such as a collapsing arch, severe knock-knee (valgus) alignment, or other foot deformities.

Summary

In summary, medial tibial stress syndrome is a multifactorial lower leg condition that results from repetitive running and jumping. Many factors are involved, but the most controllable ones are sudden changes in a training program, equipment, or the running surface. Appropriate initial treatment can control the symptoms, and the vast majority of cases resolve without the need for surgery.

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See also Athletic Shoe Selection; Lower Leg Injuries; Lower Leg Injuries, Surgery for; Orthotics; Overpronating Foot

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Medical Management of an Athletic Event

Large sporting events such as world and continental championships, the Olympic Games, and so on, require many years of preparation and planning. For the Olympic Games, work often starts 5 or 6 years before the event. It is important that medical personnel are involved early on in the process so that medical facilities can be incorporated into structural, staffing, and budget plans.

Other sporting events pose completely different challenges. Marathon races can attract up to 30,000 runners to a city in the hot summer. The Vasaloppet cross-country ski race attracts more than 14,000 participants for a 90-kilometer race in subzero temperatures. In the Paris-Dakar rally, motorists drive off-road across the Sahara desert into the arid lands of Mauritania. And in the Marathon des Sables, athletes run a marathon every day for 6 days in the Moroccan Sahara Desert. Planning such events requires detailed preparation to be successful; plans must be created for all eventualities and must encompass treatment of a large number of athletes and spectators with a variety of illnesses and injuries. Unfortunately, stadium disasters are not uncommon events, particularly in soccer arenas, where almost 200 spectators have died in the past 10 years in stadia around the world.

Mass participation events can take many forms. For a major track-and-field event, several hundred athletes may be localized in one stadium for a number of hours; from a medical viewpoint, these are relatively easy events to plan and cover, as many physicians have plenty of experience working in this type of environment. Things become more complicated when there are events occurring in several venues simultaneously, as in the Olympic Games, where one can have several events occurring simultaneously all day for 16 days. Imagine the amount of effort required to staff and equip the 219 medical stations at the 2008 Beijing Olympics (123 competition venue stations, 65 training venues and 31 non–competition venue stations—3,223 medical personnel—excluding the 834 doctors and 91 physiotherapists who traveled with the 204 national teams). The total number of medical encounters was more 21,000, of which approximately 15% were athletes and almost 50% were volunteers.

Outdoor Arenas

Many outdoor arenas cover large areas and are potentially difficult to "manage" medically. Cross-country running/skiing events are notoriously difficult, as the tracks often pass through areas without names or access routes, so appropriate maps are essential. There are many considerations to be taken into account; the only way to prepare for these scenarios is to develop and rehearse contingency plans, know your access routes, and know where your staff are located and what equipment and competence they possess. Everyone must have the same reference points.

All major sports events require a management team; the head of medical services is often called the chief medical officer (CMO) or medical director and should be a qualified physician with a sports medicine background. Medical services must often be provided from the time the athletes arrive for precompetition training and not just on the day of competition. For many sports, official precompetition training may start 4 or 5 days before the actual event, and services must be in place in varying degrees.

At a major event, medical services are usually available 24 hours/day and must be supplied to several different groups—athletes, spectators, and media persons (23,000 in Beijing). It is normal practice to offer 24-hour medical services to athletes and media persons. Similarly, visiting International Federation and International Olympic Committee (IOC) members usually have their own medical services, as do the tens of thousands of Games volunteers and the visiting state leaders and royalty. Considering that the Olympic Games are almost never located in one city any more, the services must be replicated in several venues, usually two or more. As the total number of spectators at an Olympics Games can reach 6,000,000, one must reckon with injuries and illnesses.

The centerpiece of the Olympic medical services is the central polyclinic, which is basically a mini hospital specifically built for the athletes and located in the Olympic Village. Satellite polyclinics may also need to be available if there are multiple Olympic sites. Emergency services are usually available all day for a whole month, with specialist services available from 8 a.m. to 11 p.m. daily. These include sports medicine, internal medicine, general surgery, orthopedics, podiatry, physiotherapy, gynecology, dermatology, dental care services, eye care services, ENT (ear/nose/throat), psychology, medical imaging (magnetic resonance imaging [MRI], computed tomography [CT], ultrasound, and X-ray, and laboratory services), blood and urine analysis services and even a pharmacy. The polyclinic alone may need a staff of 500 to 600 health professional volunteers.

Ambulances

Ambulance services must serve two separate groups—athletes (team staff are usually included) and everybody else. Many International Sports Federations (IFs) require two ambulances to be present at televised sporting events, either due to the fact that many of the athletes are participating in high-velocity sports (most winter sports, e.g., bobsled, Alpine skiing) and thus run the risk of multiple injuries or because the departure of an ambulance from the track may oblige the event organizer to stop the event due to IF regulations.

A motorized buggy for athlete transport from the field of play can be useful, particularly when treating spinal or cardiac patients. Athletes can be transferred on almost any kind of transport unit, cars, boats, ski-sleds, skidoos, surf boards, and so on.

An ambulance may be everything from a patient transport unit to a mobile intensive care unit. The right type of ambulance must be positioned at the right place, and it must be ensured that access routes are available and cleared if needed. At the 2008 Olympics, 191 ambulances were dedicated to the various venues.

Factors That Influence Medical Staffing Numbers

Certain sports are more dangerous than others. Motor sports are associated with serious injuries, and one can conclude that the higher the athlete's speed, the greater the risk of injury. Hence, injuries are to be expected in downhill skiing, ski-jumping, bobsled, and diving sports, so an adequate amount of appropriately skilled medical staff must be present. Water sports are always potentially dangerous due to the risk of drowning, particularly in open-water swimming. Head and neck injuries are to be expected in boxing, the martial arts, rugby, American football, and so on, while skating sports are associated with major cuts from blades, and serious falls can occur in equestrian sports. Athletes can collapse during endurance sports.

The number of spectators present dictates the staffing requirements in the spectator zones. Take, for example, the staffing of a major stadium with 70,000 people during the Olympic Games. The following staffing levels are not unusual and are often higher:

Spectator Medical Services

- Six to eight teams of two first aid responders—one nurse and one paramedic, two teams per tier
- Three to four event physicians (EPs), one for each tier of the arena or stadium
- Medical tent/cabin/room—two EPs, four nurses, and four paramedics—to treat spectators and also act as a backup in case of an emergency (the room doctors and paramedics can rotate with the stadium staff so that they can watch some of the games)
- Reserve medical and paramedical staff, in case of fallout—sickness, and so on
- Ambulances—a minimum of two, often four, staffed by two ambulance personnel each
- Ambulance standard—Europe: CEN 1/2, United States: basic life support/advanced life support (BLS/ALS)

Athlete Medical Services

- Athletics arena—two medical teams, one team at each end of the stadium by the track, composed of one EP, one anaesthetic nurse, and two paramedics (different sports have different requirements, e.g., boxing, judo, wrestling, etc., have the medical staff on the ringside)
- Athletes' medical room—two EPs, two nurses, and one physiotherapist/sports masseur
- Ambulances—two, manned by two ambulance paramedics each

Other Tasks for the Medical Director

In addition to recruiting the right number of staff, the CMO must also choose the right number of specialists and, not the least, the right people. Keeping all of these volunteers happy for a month is no easy task, and the CMO needs to have sophisticated personnel management skills.

When working with a large number of new staff, it is important to develop and distribute predetermined medical care protocols well before the start of the competition. These protocols should include topics such as emergency on-site care, the level of care to be given at various stations, where and how athletes are to be transported, who should accompany the athlete to other medical facilities, and return-to-play decisions. To help structure acceptable protocols, it is a good idea to liaise with the IF physicians, who have in-depth knowledge of the various sports and their federation requirements.

Similarly, good contact with the visiting national team physicians is important.

Staff rotation between various venues can have its advantages but also its disadvantages; familiarity with a stadium is vitally important for effective medical intervention, and frequent change of venue can cause location disorientation, particularly at the time of a crisis. However, if boredom and tedium (due to being overworked or underemployed) are becoming an issue, and there is a danger of losing volunteer medical staff, then venue rotation may be a valuable option.

Medical Log

During a large sports event, it is important to keep a log, not only as a statistical tool after the event but also to keep track of individual incidents. It is important to know where the athlete is in the treatment chain; it allows one to give information to the coach, the family, and so on. One can also have a documented chain of response in case of later review.

Athlete Injury Forms

Computer-based medical records are essential. It can take some time for the medical staff to learn and be proficient in the new medical software, so allow time for this in the precompetition period. Security issues for journalists must be addressed. All medical personnel must be made to sign confidentiality agreements.

Daily Venue Reports

During the competition, the day's event should be concluded by having a staff meeting. Each team should deliver a report on the number and severity of injuries, any hospital admissions or referrals, and special situations. There should be a short review of staffing and staff location plans. A list of used equipment should be prepared, and supplies should be replenished before the next day's event. Staff rotas for the next day should be confirmed and start time agreed on. Radios must be delivered so that batteries can be charged. The venue reports should be sent to the CMO.

Availability of Medical Services

Staff should be present at least 60 minutes before the event starts. After the event is over, keep athlete services available for 30 minutes after the award ceremony. Spectator services should be available until all spectators have left the venue. Conclude the service by having a 5- to 10-minute meeting with all medical staff to collect reports, logs and statistics, and equipment lists and to confirm that all staff will be returning the next day.

Traffic Control

A major concern is that ambulance access and exit routes can be blocked by either spectators or traffic. At larger events, there should be a dedicated road for venue vehicles, and cooperation with the police and traffic authorities is a prerequisite.

Prevention

The medical director will be intimately involved in race day planning and must be prepared to make difficult decisions in order to reduce the potential for athlete injury. In extraordinary circumstances, the CMO may recommend altering or even cancelling an event if there are severe environmental risk factors present—for example, extreme heat at a marathon, lightning, and so on. It must be emphasized that a doctor has no right to stop a race or competition; these decisions are made by the sports authorities. Major work and effort are being put into discovering the causes of injury, and huge resources are being used to prevent athletes from being injured. In many sports, certain injuries are more common—for example, back problems in divers—and one can take preventative steps by encouraging specific training programs to help protect against these conditions.

It is also vital to remind participants to wear, if pertinent to the individual, medical alert wrist braces (e.g., "I have diabetes").

Cooperation with the local health authorities in the prevention of contagious infectious diseases is another important task. Plans must be developed to combat food poisoning, water poisoning, airways diseases, and so on.

Medical Staff Clothing and Visibility

You can have the best equipment and staff in the world, but without adequate footwear and good-quality gloves when working in water or freezing weather, your ability to perform in cold, wet climates is extremely reduced. Particularly if patients have to be lifted and carried out of ditches or steep hills, rescue work can become exhausting for the medical staff. Similarly, staff working in extreme heat and sun should be supplied with appropriate, loose-fitting clothing. Sunblock cream, sunglasses, and caps are vital. Remember also that staff may have to work both indoors and outdoors, and correct clothing has to be available. It is not unusual to have a 20 to 30 °C temperature difference between indoor and outdoor conditions. Medical staff should wear similar clothes so that they are easily identifiable.

Accreditation

Access to various zones of a sports arena during a major event is extremely restricted, with good reason. It is important to allow medical personnel access to all parts of an arena, at the same time ensuring that this access is not abused. Different zones are letter or number coded, thus allowing the bearer access. Before an event, all medical staff must receive an accreditation card; they will usually have to go through a registration process weeks or months beforehand and then collect their cards at a designated accreditation center before being allowed access to any arena. It is imperative to keep your accreditation card hanging round your neck at all times so that you do not lose it!

Temporary Medical Licenses

During large sporting events, it is usual to issue licences for visiting nonnational physicians in order to allow them to practice medicine legally on their own nationals before and during an event. Visiting physicians must apply for these licences from the host nation's national health authorities many months in advance. Insurance matters must be addressed, and the visiting physicians must receive information well in advance of the competition about what rights and facilities they will have on entering the host nation. As a rule, foreign physicians are only allowed to treat athletes from their own country; they may issue prescriptions, which can be delivered to a specific pharmacy. A meeting between the host medical staff and visiting physicians is usually arranged just before commencement of the sporting event.

Language and Cultural Difficulties

Language differences do not usually create great difficulties as a rule; if you have seen the injury, then the path to diagnosis is usually clear. If not, then one can usually get some kind of history through physical demonstration. The problem gets worse when nontraumatic conditions have to be diagnosed and becomes almost impossible if there are psychiatric problems present.

Translators are necessary in certain instances. During smaller events, you can ask other volunteers, the ground staff, athlete team members, and so on, for assistance. In today's multinational world, it is not unusual to find someone who speaks the injured athlete's language. It is also advisable to have both male and female doctors available.

Equipment

Ordered equipment should be delivered in crates that have built-in shelves and should be packed in such a way that the crates, when opened, are actually stand-alone units ready for use, thus doing away with the need for extensive packing and unpacking of medical equipment.

The contents of the crates and their placement in the medical rooms should be standardized to facilitate ease of use. Sealed equipment and medications should not be used unless absolutely necessary.

Equipment that is not used can be resold or returned to the supplier after the event.

All disposable materials and medications used should be compiled on a list. This list of used and required items can be sent daily (or less frequently) by fax or e-mail to the central warehouse, and refills can thus be ordered.

At large events, it is important to have a store of disposable materials and medications. Refill orders should be sent in by a particular time each day, thus allowing refills to be delivered to the stadium during the night. Refilling, thus, will be done before the start of competition the next day.

Always test vital equipment before the start of an event. In particular, check whether the oxygen tanks are working and full, check all equipment containing batteries and bulbs, make sure there are no leakages from splints and ensure that the right pumps are available, make sure that all medications are available and are not outdated, and ensure that infusion fluids are intact and have the correct temperature.

Outfit doctors, nurses, paramedics, and first aid responders with backpacks/fanny packs containing lightweight portable equipment. The contents of the backpacks will vary according to the individual skill levels, location, number of potential patients, and so on.

Belt packs and fanny packs are usually standard and can contain items for personal use, for example, water bottles, snacks, sunglasses, gloves, and so on.

De-Rigging and Resale

After an event has been completed, a major de-rigging operation is initiated, and rooms are literally stripped bare of all equipment, including telephones and other electronic equipment. This process can begin 1 hour after the final event. The urgency and speed with which these de-rigging exercises occur is often quite staggering, and one often wonders why it takes months to outfit rooms but only hours to empty them! One motive for this haste is to prevent theft.

Although this program may appear somewhat excessive and overdimensioned for minor sporting events, the issues addressed are often equally relevant for smaller sports events, though on a much reduced scale.

In conclusion, planning the medical aspects of a sports event can be quite challenging but also most rewarding. Careful and detailed planning is always essential to ensure a quality service.

David McDonagh

See also Fieldside Assessment and Triage; Marathons, Injuries in; Team Physician

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Meniscus Injuries

One of the most commonly injured parts of the knee, the *meniscus* is a wedgelike, rubbery cushion where the major bones of the leg connect. Meniscal cartilage curves like the letter C at the inside and outside of each knee. A strong stabilizing tissue, the meniscus helps the knee joint carry weight, glide, and turn in many directions. It also keeps the femur (thigh bone) and tibia (shin bone) from grinding against each other.

Football players and others in contact sports may tear the meniscus by twisting the knee, pivoting, cutting, or decelerating. In athletes, meniscal tears often occur in combination with other injuries, such as a torn anterior cruciate ligament (ACL). Older people can injure the meniscus without any trauma as the cartilage weakens and wears thin over time, setting the stage for a degenerative tear.

Anatomy

The knee menisci are C-shaped pieces of fibrocartilage that serve as shock absorbers in the knee. Their triangular cross section serves to increase the contact area between the rounded end of the distal femur and the relatively flat tibial plateau, thus allowing for load to be transferred over a greater surface area between the two bones. The menisci also contribute to knee joint stability, joint lubrication, and proprioception. The menisci are able to slide to the front and the back of the knee as the knee flexes and rotates, with the less constrained lateral menisci (outer menisci) moving to a greater extent than the medial meniscus (inner menisci). The more limited range of motion of the medial meniscus makes it more vulnerable to tearing and injury.

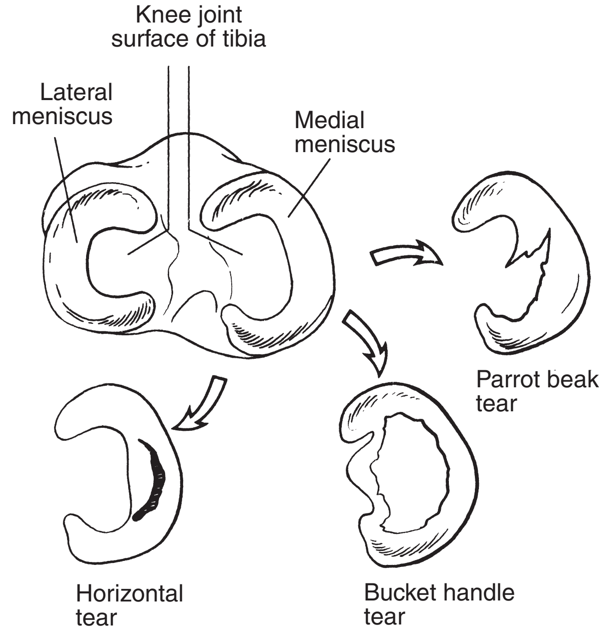

Figure 1 Meniscus Injuries

Note: Meniscus tears are named according to the shape of the tear: *bucket handle, horizontal,* and *parrot beak,* to name three.

Causes

Menisci tear in a number of ways:

Young athletes often get longitudinal or "bucket handle" tears if the femur and tibia trap the meniscus when the knee turns.

Less commonly, young athletes get a combination of tears called radial or "parrot beak," in which the meniscus splits in two directions due to repetitive stress activities such as running.

In older people, cartilage degeneration that starts at the inner edge causes a horizontal tear as it works its way back (Figure 1).

Symptoms

The athlete might experience a "popping" sensation when a tear of the meniscus occurs. Most people can still walk on the injured knee, and many athletes continue to play. When symptoms of inflammation set in, the knee feels painful and tight. For several days, the athlete has

- stiffness and swelling,
- tenderness in the joint line, and
- collection of fluid ("water on the knee").

Without treatment, a fragment of the meniscus may loosen and drift into the joint, causing it to slip, pop, or lock; the knee gets stuck, often at a 45° angle, until it is manually moved or otherwise manipulated. The athlete suspected to have a meniscal tear should see a physician promptly for diagnosis and individualized treatment.

Diagnosis

The history and physical examination are probably the most important ways to diagnose a meniscal tear. In an acute (sudden) injury, joint swelling is a good indicator. Swelling that occurs within the first few hours of an injury can be especially indicative of the injury causing bleeding in the joint, while swelling that occurs the next day may be due to the inflammatory response. In addition, examination of the knee with specific tests may be helpful in determining whether the injury is to a meniscus or another structure within the knee, such as a ligament or the cartilage.

Imaging of the knee may also be recommended. X-rays can be used to rule out a fracture, but the menisci themselves will not be visible on these studies. To assess the meniscus, a magnetic resonance imaging (MRI) scan may be ordered. In some cases, arthroscopy (putting a small camera into the joint) may be required to determine whether there is a tear in the meniscus. If this is needed, treatment of the tear can usually be accomplished at the same time.

Treatment

Nonoperative Approach

Initial treatment of a meniscal tear follows the basic RICE formula (*r*est, *i*ce, *c*ompression, and *e*levation), combined with nonsteroidal anti-inflammatory drugs (NSAIDs) for pain. If the patient's knee is stable and does not lock, this conservative treatment may be all that is needed. Blood vessels feed the outer edges of the meniscus, giving that part the potential to heal on its own. Small tears on the outer edges often heal with rest.

Surgical Repair

If a meniscal tear does not heal on its own and the knee becomes painful, stiff, or locked, surgical repair may be needed. Depending on the patient's age, the type of tear, whether there is also an injured ACL, and other factors, the surgeon may recommend arthroscopic surgery to either place sutures to repair the meniscus or to use small instruments to trim off damaged pieces of cartilage.

Orthopedic surgeons who are specialists in meniscal injury treatment have spent many years developing highly specialized arthroscopic techniques to repair tears in the meniscus. This experience has enabled repair of not only small, "simple" tears but also complex, multicomponent tears, which most physicians elect to remove, particularly in young patients. Although the success rate is lower for complex tears than for simple tears, it is felt to be worth the time and effort to try to save the meniscus in order to keep as much of the normal shock absorber in the knee as possible, especially for young patients.

In some cases, the torn part of the meniscus is either so small that it would be impractical to repair or so damaged that the repair would have a high likelihood of failure. In these cases, this tissue is simply trimmed out to leave a stable rim of meniscus and to minimize further damage within the knee.

The goal of meniscal surgery is to obtain a stable, smooth rim of meniscal tissue that does not rub abnormally on the cartilage surfaces of the knee. Patients may still have a slightly increased risk of arthritis in the knee after a meniscal tear, even if surgery is performed.

Alternatives to Surgery

Surgical treatment is usually advised for patients with symptoms of unstable meniscal tears, including pain, locking, giving way, or catching in the knee. However, deciding against surgery is reasonable for select patients. Nonoperative management of isolated meniscal tears is likely to be successful or may be indicated in patients with

- small, stable tears located in the outer third of the meniscus,
- low-demand lifestyles, and
- no effusion or swelling of the knee and no symptoms of locking or catching in the knee.

Preoperative Care

If arthroscopic surgery is elected, the patient should have a complete physical examination with the family physician before surgery to assess general health and to rule out any conditions that could interfere with surgery. Tests including blood samples and a cardiogram may be ordered.

Preoperatively, the patient must be informed which medications to discontinue prior to surgery. These typically include aspirin and anti-inflammatory medications such as ibuprofen, which should be stopped 10 days before surgery.

Rehabilitation

Nonsurgical Rehabilitation

Nonsurgical rehabilitation for a meniscal injury will typically last 6 to 12 weeks if no mechanical symptoms are present (symptoms such as locking, catching, or giving way). This will consist of exercises to strengthen the muscles around the knee, avoidance of high-impact activities, and possibly use of a brace to stabilize the knee during the healing process. The patient can return to full activities when there is no more swelling in the knee, the pain subsides, and the patient has regained complete strength and control of the knee.

After Surgery

A cast or brace immobilizes the knee after surgery. The patient must complete a course of rehabilitation exercises before gradually resuming normal activity.

Most patients will take part in formal physical therapy after meniscal surgery. In cases where only a small trimming was needed, many patients find that gradually resuming their normal activities as their knee strength and control return is effective and safe. Patients who have had a repair of the meniscus will often need formal physical therapy to regain strength and motion within the knee as the meniscus heals.

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See also Knee Injuries; Knee Injuries, Surgery for; Musculoskeletal Tests, Knee

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Menstrual Cycle and Sports Performance

The female menstrual cycle (MC), with its alternating levels of sex steroid hormones, affects exercise capacity and performance through numerous mechanisms, such as substrate metabolism, cardiorespiratory function, thermoregulation, psychological factors, and injury rates. Female athletes and their coaches should be aware of both positive and negative influences of the MC on overall performance, on an individual basis. Athletes negatively affected by their MC can consider the use of oral contraceptives to provide a stable and controllable hormonal milieu for training and competition. It should be noted that this is a very complex field, and future research will undoubtedly shed more light on the mechanisms and outcomes detailed below.

The Menstrual Cycle

The MC can be divided into three phases based on ovarian function—follicular, ovulatory, and luteal—all of which are controlled by pituitary hormonal signals. The *follicular phase* begins on the first day of menses, lasts about 9 days, and is the period when the follicle (soon to be an ovum) grows. Estrogen is secreted from the cells surrounding the follicle to the circulation. As estrogen levels increase, ovulation occurs, and an ovum is released and starts to migrate to the uterus. This marks the beginning of the *ovulatory phase*, which lasts about 5 days. After the follicle has released the ovum, it transforms into a progesterone-secreting corpus luteum, marking the beginning of the *luteal phase*, which normally lasts 14 days. At the end of the luteal phase, progesterone secretion from the corpus luteum ceases, and menstrual bleeding occurs. The three phases of the cycle are therefore differentiated from one another by estrogen and progesterone levels: Both are low in the follicular phase, estrogen is high and progesterone is low in the ovulatory phase, and both are high in the luteal phase. The sex hormones have several physiological functions, which can affect exercise performance through several mechanisms.

Physiological Effects of the Sex Steroid Hormones

Cardiovascular System

Estrogen enhances arterial vasodilatation, which in turn can increase blood supply to the heart and muscles. Estrogen and progesterone (high in the end-luteal phase, i.e., premenstruation) can cause fluid retention and increase in body weight, which might hinder performance. Additional effects on heart function have been documented, but not enough research has been done in this field.

Respiration and Ventilation

Sex hormones are involved in the central neural control of breathing, also affecting the lungs and the airways. Furthermore, premenstrual and perimenstrual aggravation of asthma can be seen in up to 40% of asthmatic women, even though they may not be aware of it.

Thermoregulation

Progesterone causes an increase in basal body temperature of 0.3 to 0.5 °C during the luteal phase (and during pregnancy). The major mechanisms of this phenomenon are altered skin blood flow, a higher threshold for cutaneous vasodilatation, and delayed onset of sweating. A higher core body temperature may increase the risk for heat accumulation when exercising in hot weather, thus decreasing time to fatigue.

Substrate Metabolism and Energy Sources

Estrogen promotes glycogen uptake and storage in both liver and muscle. During exercise, higher levels of estrogen (and progesterone to a lesser extent) tend to spare glycogen stores by shifting metabolism toward free fatty acids. This may be an advantage during ultraendurance exercise. Estrogen can also act in concert with additional hormones regulating glucose metabolism, such as growth hormone, catecholamines, and insulin. Progesterone is probably responsible for the relative glucose intolerance and insulin resistance during the luteal phase and pregnancy.

Psychological Factors: Estrogen and the Brain

There is evidence that estrogen mediates different aspects of cognition, alertness, and mood, possibly through changes in the availability of neurotransmitters such as serotonin in the brain. The importance of these effects is mainly during competition, where peak mental functions are required.

Menstrual Cycle and Physical Performance

The physiological changes throughout the MC may affect physical performance. The main factors for discussion are strength and aerobic and anaerobic capacities. Since there is great variation between individuals, it is essential for each woman to monitor her own response.

Strength

Estradiol can promote growth hormone secretion, a hormone known for its anabolic effects. Some research suggests that estrogen increases the ability of muscles to contract by about 10%, with a peak in strength just before ovulation. Others show that maximal muscle contraction is significantly higher during the ovulatory phase but there are no significant changes in muscle strength, fatigability, or electrically stimulated contractile properties. To date, there is no consensus on this matter.

Aerobic Capacity

Some studies suggest a slight decrement in aerobic capacity and exercise efficiency during high-intensity exercise in the luteal phase, paralleling an increase in oxygen consumption and metabolic rate. However, these results are not consistent. Aerobic endurance is also a matter of controversy, with some studies suggesting improvement during the luteal phase. However, it is more likely that nutritional status, glycogen stores, and other hormonal effects on substrate utilization contribute more to enhancement of performance than the MC phase itself.

Anaerobic Capacity

The few studies conducted in this area have found either no difference in anaerobic power output during the different phases of the MC or greater anaerobic capacity and peak power during the luteal phase.

Menstrual Cycle and Overall Sport Performance

While the MC can affect physiological and metabolic responses to exercise, optimal performance in a specific sport type is the ultimate goal of the female athlete. The aerobic effects of the hormonal fluctuations may be more relevant to a long-distance runner or biker, whereas strength is important for the weight lifter, fluid retention for the high jumper, and so on. Because maximal function in a sports event depends on a combination of physiological and psychological factors, it is very difficult to isolate the effects of the MC on overall performance. Most of the early studies on athletic performance were based on subjective feelings, without measuring the hormone levels. Many athletes reported a decrease in performance during the premenstrual and menstrual phases, whereas others reported improved performance, winning gold medals and breaking world records. When asked which symptoms of the MC hinder their performance, athletes reported abdominal or low back pain, fatigue, or nervousness during menstruation, yet most did not feel that these symptoms affected their ability. Gold medals were won throughout the female cycle, emphasizing that menstrual phase effects are individual.

Very few studies have intentionally addressed MC and performance in specific sports. For example, swimming speed was found to be highest during menstruation and lowest during the premenstrual period; cross-country skiers performed better in the early luteal and in the late follicular phases; in runners, no effect of MC phase on aerobic parameters or perceived exertion was identified. However, these kinds of studies usually involve only a few athletes, and a menstrual phase is not verifiable by blood tests, only through self-report or body temperature changes. Hence, the influence of the MC on the "end result" of performance in a particular sport type per se is not known, so every athlete should examine the effects of her own MC on her sports performance.

Menstrual Cycle and Sports Injuries

Females have nearly 10-fold the rate of sports injuries as males. This has been found in playing ball games, running, biking, military training, and other activities. Suggested mechanisms that may be affected by the female hormones include anatomical and biomechanical factors, neuromuscular control, ligament laxity, and others. Most studies focus on knee injuries and the changes in laxity of the anterior cruciate ligament (ACL) throughout the MC.

Recent studies, which use measurements of hormone levels, show a clustering of ACL injuries in the ovulatory phase, that is, Days 10 to 14 of the MC, with a lower than expected rate of events during the luteal phase. Suggested mechanisms for the higher rate of ACL injury in females in general and during the ovulatory phase in particular include changes in neuromuscular control, muscle strength and fatigability, and the intensity of the premenstrual syndrome and its effects on balance and motion perception. Much attention has been given to the increased laxity of the ACL during the luteal phase, which is associated with higher hormone levels.

Oral Contraceptives

Oral contraceptive pills (OCPs), which provide a steady level of high estrogen and progesterone, are increasingly being used by female athletes. They allow manipulation of the timing of menses; it is possible to even completely withhold menstruation with the use of new pills such as Seasonale®, which is administered for 3 months continuously, allowing only four "periods" of withdrawal bleeds per year. The latter method abolishes premenstrual syndrome and menstrual discomfort and pain, decreases blood loss and iron deficiency, and, of course, prevents unwanted pregnancies.

As discussed so far, research indicates that regularly menstruating female athletes do not need to adjust their MC to maximize performance, as hormonal changes during the MC and any physiological and psychological effects they may inflict differ greatly from one woman to another. If OCPs are used to minimize the identified negative effects of menstruation on sports performance, then regular use of OCPs will give a stable hormonal milieu and predictable onset of menstrual bleeding. Hormonal manipulation of the MC should be restricted to mature, elite athletes and reserved only for critical competitions in cases where there is a clear deleterious effect of the menstrual phase on performance.

Conclusion

The changes in estrogen and progesterone levels throughout the MC cause several biochemical, anatomical, physiological, and psychological effects on a female's body, which in turn may affect sports performance. The paucity of research in this field, and the varied methodologies used, prevents us from drawing distinct conclusions other than the following: The net sum of these changes may bring about positive or negative effects on sports performance *on an individual basis,* so athletes and coaches should "listen to the body" and act accordingly. Use of hormones can be considered in specific cases where the MC is shown to negatively affect sports performance. For those who need contraception, continuous pills can be a new, promising option.

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See also Amenorrhea in Athletes; Anterior Cruciate Ligament Tear; Bioenergetics of Exercise and Training; Cardiovascular and Respiratory Anatomy and Physiology: Responses to Exercise; Dysmenorrhea; Exercise Physiology; Female Athlete Triad; Menstrual Irregularities

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Menstrual Irregularities

The average age for girls to first have a period (undergo menarche) is 12 years. However, it is normal to experience menarche between the ages of 8 and 15. Menopause, when a woman has her last menstrual cycle, occurs at an average age of 51 but is normal between the early 40s and late 50s. Genetics, diet, and activity level all affect the age of menarche and menopause.

The Menstrual Cycle

The normal cycle is about 28 days (±7 days), and it is common for the cycle to be of slightly different lengths from month to month. In the first year or two after menarche, it is common to have even more variability, as the body adjusts to menstruation. When a woman experiences cycles within the normal range, it is called *eumenorrhea.*

The first day of the menstrual bleed is considered Day 1 of the cycle and begins the *follicular phase.* Normal menstrual bleeding, the shedding of the endometrial lining of the uterus, usually lasts from 3 to 5 days. As menses ceases, hormonal changes lead to the buildup of the endometrial lining again and the growing of follicles in the ovaries. While still part of the follicular phase, this subphase after menses is considered the *proliferative phase,* when the endometrial lining is thickening and the follicles are growing. Eventually, one follicle dominates, and around Day 14, it releases what becomes a mature ovum, or egg, from the ovary. This is ovulation.

The ovum travels into the fallopian tube, awaiting fertilization, while the endometrial lining develops secretory glands to prepare for implantation. The corpus luteum, what remains of the dominant follicle after the ovum is released, grows and secretes hormones to help maintain the endometrial lining. This is the beginning of the luteal phase or secretory phase, the second half of the menstrual cycle. If the ovum is not fertilized, it disintegrates, as does the corpus luteum; hormone levels fall, and eventually, the endometrial lining is shed (menstruation and Day 1 of the next menstrual cycle).

There are a variety of hormonal changes that occur during the menstrual cycle. Pulsatile secretion of gonadotropin-releasing hormone (GnRH) from the hypothalamus (an organ in the brain) stimulates the production of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) in the pituitary gland (another organ in the brain), which affects the levels of important hormones involved in the menstrual cycle, including estrogen and progesterone. The menstrual cycle is a complex positive and negative feedback system of an array of hormones and endocrine glands.

Importance of Normal Menstrual Function

Normal hormone levels are important for bone health, fertility, cardiovascular health, and other biological functions. For example, women attain 90% of their peak bone density by the time they are 18 years of age. If menstrual cycles do not occur during adolescence, a significant opportunity for bone building will be lost, putting the individual at much higher risk for fractures immediately and later in life. Thus, abnormal menstrual cycles should always be investigated. First and foremost, they may signify pregnancy! But they may also signify lack of nutrition, excessive exercise, polycystic ovarian syndrome, a thyroid disorder, uterine polyps, fibroids, endometrial fibroids, diabetes, a drug effect, infection, or other health problems. The following are signs that a female should see her doctor about her menstrual cycle:

- She has not started menstruating by the age of 15 even though she has secondary sex characteristics (e.g., breast development, axillary and pubic hair). This is known as *delayed menarche* or *primary amenorrhea*.
- She has not had breast growth by the age of 13 (*delayed puberty*) or hasn't started menstruating within 3 years of breast development (also *delayed menarche*).
- She has experienced menarche but suddenly has no menstrual cycles for >90 days (*secondary amenorrhea*).
- She has menstrual cycles that are >35 days (*oligomenorrhea*).
- She has menstrual cycles that are <21 days (*polymenorrhea).*
- She has breakthrough bleeding during her cycle at unexpected intervals (*metrorrhagia*).
- She bleeds for >7 days (*menorrhagia*).
- She bleeds more heavily than usual or is using more than one pad or tampon every 1 to 2 hours (also *menorrhagia*).
- She has severe pain during menses (*dysmenorrhea*).
- She suddenly gets a fever and feels ill after using tampons.

If a woman has testing done that determines that she has *luteal suppression* (menstrual cycles with a luteal phase shorter than 11 days or with a low concentration of progesterone) or if she has *anovulatory* cycles (no ovulation), these should also be further evaluated.

Menstrual Irregularities in Athletes

Female athletes, often in weight-restricted sports, aesthetic sports, and/or endurance sports, are at higher risk for menstrual irregularities. This is because of the *female athlete triad* (the interrelationship of poor bone health, menstrual dysfunction, and disordered eating). Oligomenorrhea or amenorrhea may be the first sign that an athlete has the triad. A fracture, stress fracture, or stress reaction may be a sign that an athlete is missing periods and has disordered eating (not enough calories, poor nutritional choices, or pathologic eating patterns such as anorexia or bulimia).

Because estrogen and other hormones involved in the menstrual cycle are so important for bone health, skipping periods should not be accepted as "normal" among athletes. Menstrual irregularities can compromise long-term health as well as athletic performance. Some women will take an oral contraceptive pill (OCP) to ensure that they do get menstrual bleeds, but the hormones in "the pill" do not mimic the hormonal fluctuations of a normal menstrual cycle. Thus, while OCPs may help with dysmenorrhea, menorrhagia, metrorrhagia, acne improvement, pregnancy prevention, and other health issues, they have not been proven to be helpful in maintaining or improving bone density as well as they have in retaining or regaining regular periods. Ongoing studies are being conducted to determine the short- and long-term effects of OCPs on bone and other health parameters. For now, OCPs should be used with caution in athletes who have experienced menstrual irregularity, and a bone density test may be warranted in these athletes before routine use of OCPs.

Summary

There are many types of menstrual irregularities, all of which should be evaluated by a doctor. Some may be easily managed with changes in diet, exercise, or medication, but the abnormality could mask a more severe disorder, and ignoring it may put a woman at risk for further health problems.

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See also Eating Disorders; Female Athlete Triad

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Mental Health Benefits of Sports and Exercise

Mental health can be broadly defined as how we feel, think, and behave. Exercise is believed to boost mental health, enable us to cope better with stress, and also help in treating a number of mental disorders. Mental disorders include conditions such as depressed mood and anxiety, dementia and cognitive decline, and various psychoses, such as schizophrenia. Since poor mental health not only reduces a person's quality of life but also increases the risk for various physical diseases, this is an important topic in sports medicine.

Depression and Mood State

Mood describes a set of affective states—such as fatigue, vigor, or anger—that we experience on a daily basis. Mood is generally assessed using questionnaires that ask people to rate how they are feeling on a scale. There are a large number of studies that have examined the association between exercise and mood. Acute effects refer to the mood response from a single bout of exercise, while chronic effects describe how mood alters with involvement in regular exercise over time. Following a single bout of exercise, mood is generally enhanced. Immediately after vigorously exercising, there may be a short period of increased negative mood state, such as fatigue, but positive mood is still enhanced some time later. The positive mood response to acute exercise is potentially important because it provides the motivation to maintain regular exercise habits. When people who exercise regularly are forced to stop their normal physical activity, it is known to be a powerful and stressful stimulus that can induce depressive and fatigue-like symptoms. This is an important factor to consider when injury prevents athletes from continuing with their normal exercise training.

Depression is a common mental disorder and has gained a lot of interest in relation to exercise. Depression is recognized from various symptoms that include depressed mood, loss of interest and pleasure, feelings of guilt and low self-worth, disturbed sleep and appetite, low energy, and poor concentration. Research in large populations suggests that people who exercise regularly are less likely to suffer from depression throughout their lives. These results are observed when other factors are also taken into account, such as social class, education, employment, marital status, smoking, and alcohol intake. Nevertheless, it remains unclear whether exercise is a cause of better mental health or whether regular exercisers have a particular genetic makeup that makes them less prone to depression in the first place. To resolve some of these issues, researchers have attempted to see if exercise can reduce levels of depression when individuals are randomly allocated to exercise training or control treatments.

Results from these studies suggest that exercise can consistently reduce symptoms of depression in both adults and children. The present research, however, has not been able to establish if the antidepressant effects of exercise can be maintained over a long period of time. This information will be important if exercise is to become an established treatment for depression.

Depression has been strongly linked with premature death, and cardiovascular disease, in particular. Physical illness, especially chronic or severe diseases, is associated with a substantially higher prevalence of depression than good physical health. It is therefore important to consider the use of exercise to improve physical health outcomes in clinical populations with existing mental health disorders such as depression. For example, among cardiac patients with depression, those who exercise regularly have been shown to have a lower risk of subsequent death and heart attack. Therefore, treating depression with exercise appears to have additional benefits over and above medication.

Age-Related Cognitive Decline

Cognitive decline, which refers to loss of memory and the ability to concentrate and make decisions, presents a major problem in aging communities. Dementia is a common disease and is characterized by a decline in memory. Various longitudinal studies have shown that people who exercise regularly are less likely to develop dementia at a future time point. Walking for a minimum of 1.5 hours/week is associated with better cognitive performance in older women, although reducing physical activity levels over a period of 10 years might result in cognitive decline. In studies where individuals are randomly allocated to exercise training or control treatments, exercise has been shown to consistently improve cognitive function. These benefits are seen both in healthy people and in older people with existing cognitive impairment. For example, individuals with Alzheimer disease who exercise show improved function on activities of daily living, better cognitive performance and physical function, and decreased depressive symptoms, in comparison with nonexercisers, who show continued decline. However, in most of these studies, exercise training interventions have been conducted for 6 months or less, and longer-duration studies are therefore required to confirm the long-term benefits.

Stress Buffering

Stress is a common aspect of everyday life, and although a certain degree of stress is beneficial to stimulate mental and physical performance, the inability to cope with excessive psychological demands may be detrimental. People who are physically fit or engage in regular physical activity show reduced responses to stress. Such responses include lower blood pressure, lower immune activation, and reduced release of various stress hormones, such as adrenaline and cortisol. Exercise might be particularly beneficial for people who are already suffering from mental health problems because these individuals display heightened responses to stress. And exaggerated responses to stress may further contribute to a worsening of their condition.

The beta endorphins, which are produced during exercise, have often been related to the positive affective states observed following exercise and have also been associated with stress-buffering characteristics. In addition to various exercise-induced adaptations to the central and peripheral nervous system, this may form the basis for the mental health benefits of exercise. It is, however, possible that the additional benefits gained from participating in sports may have a psychological component, such as fostering social support networks and developing mastery and better coping abilities.

Prescribing Exercise

It is important to define the amount and type of activity required to achieve mental health benefits. The current recommendations for physical activity for preventing chronic disease are at least 30 minutes of moderate to vigorous exercise on 5 or more days per week. However, the existing evidence suggests that mental health benefits can be gained from lower amounts of physical activity. A minimum of one session (of at least 20 minutes) per week of any type of activity, including domestic work, walking, and sports, can be beneficial. However, exercising vigorously (e.g., sports participation) and more frequently (everyday) seems to give the most benefit. From a practical standpoint, several components of mental disorders, such as fatigue, low self-esteem, and other physical ailments, might make it difficult for people with poor mental health to begin and sustain an exercise program. Indeed, patients with depressive symptoms appear to be the least likely to take up regular exercise. Therefore, a key aspect is not only prescribing exercise but also motivating and supporting people with mental disorders to become physically active.

Another important aspect to consider is the relative benefits of structured compared with lifestyle exercise programs. Structured exercise is usually supervised and performed in an exercise facility, whereas lifestyle interventions might encourage people to use more exercise in their daily lives, such as walking instead of taking the car. Both approaches have advantages and disadvantages. For example, structured exercise ensures a safe environment to exercise in, appropriate exercise levels can be easily monitored, and exercise professionals can provide motivation and support. On the other hand, individuals with mental health problems might feel particularly self-conscious about exercising in this type of environment. A home-based exercise program may therefore be more appealing and give greater flexibility, although self-motivation and self-monitoring of physical activity goals are major difficulties with this approach. Taking all of these factors into consideration, when prescribing exercise for mental health, programs that are tailored to the individual are most likely to prove successful.

Mark Hamer

See also Benefits of Exercise and Sports; Psychological Aspects of Injury and Rehabilitation; Psychology of the Young Athlete; Sport and Exercise Psychology

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Metatarsalgia

Metatarsalgia is defined as pain at the ball or forefoot, usually associated with increased stress over the metatarsal head area.

It is a relatively common problem seen in primary care but is very common in some sports, especially in running. It can be seen in athletes of all ages, with Freiberg disease more specific to adolescents and fat pad atrophy to the elderly. Metatarsalgia also occurs in patients of all shapes and sizes, with obesity contributing to pressure-related pain on one end of the spectrum and overly thin ultraendurance athletes developing stress fractures on the other.

The metatarsals take up to 275% body weight during running, with the first metatarsal usually bearing half the weight. Biomechanical deficits involving the entire kinetic chain, whether it is genu valgus, tight heel cord, or severe pronation, all contribute to metatarsalgia.

There are many causes of metatarsalgia, and thus, a thorough history and physical and judicious imaging are critical for proper diagnosis. Treatment can vary from simply rest to, rarely, surgical management.

Symptoms

The pain of metatarsalgia is usually described as sharp, although sometimes it may be a burning or tingling sensation at the ball of the foot. The most common areas are usually the second, third, or fourth metatarsals. Patients may complain of worsening of the pain with walking or running, usually during the midstance or push off phase. The pain may improve with rest or non–weight bearing. There may also be pain with just standing. Pain is usually worse when associated with barefoot walking on hard surfaces.

Usually, the pain develops gradually and is not necessarily associated with any trauma. Sometimes, if a neuroma is involved, there may be numbness of one or multiple toes.

The history should also include a thorough training history, either increases in mileage or intensity. The type of terrain can play a role if the athlete mostly trains on hard surfaces such as concrete. Age of training footwear (generally recommended to be replaced every 300–500 miles [mi; 1 mi = 1.61 kilometers]) can definitely play a role. A new shoe that may not be appropriate to the athlete's foot mechanics can also contribute to the pain; for instance, a motion control shoe on an athlete with pes cavus and supinates may not provide enough shock absorption.

Causes

Metatarsalgia is often seen in the context of increases in training. Increased training increases the repetitive load, increasing the risk for stress fracture, fat pad atrophy/contusion, sesamoiditis, and breakdown of shoe cushioning.

Certain physical characteristics also increase the risk for metatarsalgia. A longer second toe than the first one shifts more weight to the second metatarsal head. Weight gain can obviously increase the load on the metatarsals. Hammertoes (flexed, curled toes) due to high heels or shoes that are too small cause depression of the metatarsal heads. Bunions (hallux valgus) result in a hypermobile and weak first toe, which offloads pressure to the second metatarsal. Fat atrophy from aging can be a risk for the elderly.

Shoe wear can definitely play a role in the development of metatarsalgia. As previously stated, old shoes that have lost their cushioning ability will more directly transmit shock. Toe boxes that are too narrow can irritate a neuroma due to constant compression. Daily wearing of high heels will place extra load on the metatarsals. Shoes that are too small can be a common problem, especially in new marathoners who do not take into account the swelling caused by long hours of running.

Metatarsal stress fractures are usually found in the setting of a runner with increased levels of training. Commonly, it will involve the second, third, or fourth metatarsals, in that order.

Morton or interdigital neuromas are perineural fibrosis of the intermetatarsal plantar digital nerves causing a mechanical entrapment neuropathy. They usually occur in the third and second interdigital spaces as a result of overly narrow shoes. Besides pain, often there is a sensation of numbness, tingling, and burning.

Freiberg disease is a condition where microtrauma at the metaphysis and growth plate in adolescents results in avascular necrosis of the second metatarsal.

Pain can also come from the sesamoids—the two semilunar-shaped bones. The medial sesamoid is known as the tibial, and the lateral is known as the fibular. They are usually embedded in flexor hallucis brevis, which inserts into the base of the first proximal phalanx. They can fracture acutely or as stress fractures, or they can be inflamed from repetitive trauma. A bunion deformity (hallux valgus) can also rotate the sesamoids laterally into a greater weight-bearing position. The pain from a sesamoid injury is typically beneath the head of the first metatarsal.

Other causes of metatarsal pain include gout, infection, capsulitis, osteoarthritis, rheumatoid arthritis, and radicular or referred pain from the lumbar spine.

Physical Examination

Physical exam in the evaluation of metatarsalgia begins with inspection. This includes basic evaluation of gait and the entire kinetic chain to evaluate for risk factors and causes of the pain. On inspection of the foot, one should note not only signs of obvious deformity from trauma but also hallux valgus, pes cavus or planus, excessive pronation, and hammer toes. The examiner should also look for signs of infection or inflammation (i.e., gout or cellulitis) if there is erythema or warmth.

Generally, there will be tenderness to palpation over the affected metatarsal.

Range of motion may be increased at the first metatarsal phalangeal joint. Range of motion may be reduced at the ankle with a tight Achilles tendon, resulting in greater weight transfer to the forefoot.

There may be pain with squeezing the metatarsals together (the "squeeze test") if there is a neuroma. A severely affected neuroma may also cause paresthesias or numbness reproducible on exam.

The diagnostic procedure includes a local digital nerve block with a few milliliters of 1% or 2% lidocaine block just below the transverse tarsal ligament to diagnose neuroma.

Diagnostic Testing

Radiographs are usually obtained because they evaluate bony causes of metatarsalgia fairly quickly and at a low cost. Usually, anterior-posterior and lateral views of the foot are sufficient to detect signs of an acute or stress fracture, osteoarthritis, or a widened and flattened second metatarsal and sclerotic/irregular joint in Freiberg disease.

No further imaging study is usually needed. If there is a high suspicion of stress fracture, a bone scan or magnetic resonance imaging (MRI) study may be helpful. An MRI scan may also help in the case of atypical presenting symptoms or exam findings with persistent pain to evaluate for stress fractures, neuromas, sesamoiditis, or lumbar radicular pain.

Treatment

The initial treatment for metatarsalgia generally involves rest, ice, and elevation, as with most sports-related injuries. Non–weight bearing should be considered if there is any pain with walking. Nonsteroidal anti-inflammatories may be helpful, especially if the metatarsalgia is due to capsulitis or gout.

Subsequent treatments should be geared to the causes and risk factors associated with the injury. It may require adjusting of training schedules and goals, cross-training to reduce higher-impact activities, modifying the terrain the athlete trains on (i.e., grass instead of concrete), or recommending new footwear. Weight loss may be a critical factor if obesity or recent weight gain is the primary cause.

If there are biomechanical deficits, they need to be addressed. For example, the athlete may need to focus on stretching the Achilles tendon or correcting pronation either through posterior tibialis strengthening or through improved shoe selection.

Shoes may need to be more supportive in athletes with metatarsalgia who have pes cavus (high arches) and should have more motion control features for athletes who have pes planus and tend to overpronate. All patients who suffer from metatarsalgia should avoid high heels and shoes that have narrow toe boxes or are obviously too small.

Over-the-counter or custom orthotics can be helpful to address pronation as well. And metatarsal pads can be a quick and low-cost method to unload pressure from the metatarsal heads by spreading them apart. They can be applied in numerous shoes and adjusted easily as needed. A hypermobile first toe may be controlled with taping to minimize movement, specifically dorsiflexion, to relieve pressure on the metatarsals and sesamoids.

Generally, callus does not need to be debrided as it is a consequence of biomechanical problems and not the primary cause of pain. Debridement risks infection without significant benefit.

As mentioned above, an injection that includes an anesthetic with some long-acting steroids can be not only diagnostic but also therapeutic for Morton neuroma.

Rarely is surgery indicated in the treatment of metatarsalgia, but if it is necessary either in the form of excision of a neuroma or as a metatarsal osteotomy, a board-certified orthopedic surgeon trained in foot and ankle injuries would be best qualified.

John K. Su

See also Foot Injuries; Obesity; Orthotics; Running Injuries

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Methicillin-Resistant *Staphylococcus Aureus* Infections

Among the many bacterial skin infections that affect athletes, none have gained as much recognition or public awareness in recent years as the methicillin-resistant *Staphylococcus aureus* (MRSA) infections. There have been numerous reports of serious infection and even death from these bacteria, and the public and health care system are now in a state of alert to tackle this relatively new threat. The vast majority of MRSA infections in athletes are skin infections, although any organ system can be affected. Athletes, parents, coaches, athletic trainers, and other medical providers all have a responsibility to minimize the impact that these infections have on the affected individual and other athletes around that person.

Microbiology

Staphylococcus bacteria species are common skin bacteria present in a large proportion of the population. Under normal circumstances, they do not cause infection. Risk factors that may lead to infection, however, are unfortunately common among athletes and include skin abrasions and wet environments. The majority of these *Staphylococcus* bacteria are susceptible to penicillin-type antibiotics (methicillin has become the standard marker antibiotic of this type) and are called methicillin-sensitive *Staphylococcus aureus* (MSSA). Those strains that are resistant to methicillin are also resistant to most penicillin-type antibiotics and are called methicillin-resistant *Staphylococcus aureus* (MRSA) strains.

It is important to further distinguish between hospital-acquired methicillin-resistant *Staphylococcus aureus* (HA-MRSA) and community-acquired methicillin-resistant *Staphylococcus aureus* (CA-MRSA) strains. The former has been identified for decades, and it is associated with risk factors of recent hospitalization, significant immunocompromisation, and recent antibiotic use. These infections are usually limited to hospitals and nursing homes. In contrast, CA-MRSA has been a recognized problem in the athletic community only since the 1990s and can affect individuals regardless of these risk factors. We will focus in this entry on CA-MRSA due to its impact on athletes.

There are numerous strains of CA-MRSA bacteria identified throughout the world, and microbiologists are continuing to search for the specific factors that affect the virulence (severity) of the bacteria. This is of particular importance since the impact of infections range from a simple abscess, such as a pimple, to sepsis (blood infection with organ involvement) and even death.

Epidemiology

The prevalence of CA-MRSA in any given community varies widely. Among athletic teams, there have been reports of more than 25% carrier status, although most of the carriers did not have active infections. Identical strains of CA-MRSA have been found among teammates and competitors, indicating close contact as a high risk factor for transmission. Other risk factors for transmission include skin-to-skin contact, shared athletic equipment, and perhaps even shared artificial turf. These factors make quarantine, appropriate hygiene, and prompt identification of the problem essential in prevention strategies, as discussed below.

Clinical Presentation

Any skin or soft tissue infection (SSTI) characterized by warmth, redness, pain, pustules, or boils should be suspected for *Staphylococcus* infection and thus, by extension, CA-MRSA infection. This includes erysipelas (superficial redness of the skin from infection), cellulitis, folliculitis, impetigo, furuncles, and abscesses. Any athlete who has such symptoms should report them immediately to his or her coach or to medical personnel. Likewise, coaches or trainers of such athletes should facilitate medical evaluation.

MRSA infections are more likely than MSSA infections to form abscesses or other "closed" infections, although this is by no means an accurate method of diagnosis since there are a wide range of presentations of both. The only definitive way of differentiating an MRSA infection from an MSSA infection is by obtaining a culture and testing it in the lab for antibiotic sensitivity. Because of the potential rapid progression of symptoms that can be associated with MRSA infections, any skin infection in an athlete that is accompanied by fever, chills, malaise, or other systemic signs of illness warrants urgent evaluation in an emergency room or hospital setting.

Treatment

Treatment options for a skin infection in an athlete will vary somewhat based on the severity and type of infection, the overall health of the individual, how closely he or she can be monitored by a health professional, and the prevalence of CA-MRSA in an area. In areas with high prevalence of CA-MRSA or for athletes with known contacts with a CA-MRSA strain, treatment should be initiated with the assumption that a resistant organism is causative. There is ongoing discussion and research on optimal treatment strategies, which keep changing frequently.

For an athlete with a simple "closed" infection, such as an abscess or furuncle, who is otherwise healthy and has good medical follow-up, sterile incision and drainage by a medical provider may be the only needed intervention. Antibiotics, however, are often also prescribed. A larger lesion may need to have a surgical wick inserted to continue to drain the infection. If the medical provider has any question about whether the infection is CA-MRSA, he or she may take a sample and send it for evaluation for a definitive answer.

For diffuse CA-MRSA infections such as erysipelas, cellulitis, or any infection affecting a sensitive area (groin, hands, or face), antibiotics are almost always prescribed. Oral antibiotics most commonly recommended are trimethoprim/sulfamethoxazole, doxycycline, clindamycin, or linezolid. Some providers combine two of the above antibiotics, particularly in more serious infections. The duration of treatment is usually 10 to 14 days. Medications traditionally used for MSSA infections are not effective against MRSA and include cephalexin, amoxicillin, methicillin, azithromycin, clarithromycin, or quinolones (ciprofloxacin, levofloxacin). These antibiotics may, however, be used initially to treat an infection, with close monitoring to see if the patients are responding; if not, these antibiotics are stopped, and an antibiotic that treats CA-MRSA infections is given instead.

Severe MRSA infections include those with widespread or deep infections, involvement of a joint, or any associated systemic involvement (fever, chills, or malaise). These infections can be life threatening and require urgent hospital or emergency room evaluation. Any athlete presenting with these symptoms should proceed to an emergency room without delay. Intervention in this case usually involves hospitalization and use of intravenous antibiotics such as vancomycin.

Athletes who have had an infection or have been exposed to someone with MRSA may carry the bacteria in their noses, groins, or elsewhere on their skin, even if they have no active infection. Such people are termed *carriers*. There is conflicting evidence on the effectiveness of trying to eradicate MRSA from such carriers. The majority of studies show that attempts at eradication using a topical antibiotic such as mupirocin with or without oral antibiotics are usually not effective in removing the bacteria for any extended period.

Return to Sports

No athlete with a skin infection should play if there are also any systemic signs of illness. In the absence of systemic infection, coaches, trainers, and doctors need to consider the risk of contagion as well as the risk to the affected individual. There are no universal guidelines for return to play for MRSA, and established guidelines such as those from the National Collegiate Athletic Association (NCAA) or the National Federation of High Schools for bacterial skin infections and return to wrestling should be used as a conservative baseline. These guidelines prohibit an athlete from competing in contact or collision sports with an open, draining infection, and they also recommend being on antibiotics for 2 to 3 days prior to return to play. It is unclear as to whether these guidelines are applicable to individual or noncontact sports such as track events. With regard to MRSA infections, institutional and local guidelines are under constant review and change.

Prevention

Good personal and institutional hygiene are essential in preventing spread of the disease among teams and competitors. Measures such as simple hand washing are very effective in cutting down on infection and carrier rates. Athletes should not share personal equipment or personal hygiene items (towels, razors, deodorant, etc.) and, as discussed above, should let a coach or trainer know immediately if they have a skin infection. Strict quarantine of an infected athlete from competition, other team members, and facilities should be followed without exception. Appropriate disinfectant procedures of gym equipment or other shared equipment should be completed. Although there are many commercially available synthetic turf disinfectants, none has been conclusively shown to decrease MRSA transmission.

Peter E. Sedgwick

See also Dermatology in Sports; Infectious Diseases in Sports Medicine; Skin Conditions in Wrestlers; Skin Disorders Affecting Sports Participation; Skin Infections, Bacterial

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Miserable Malalignment Syndrome

Anterior knee pain in children and adolescents, often assigned the vague diagnosis of "patellofemoral syndrome," may have a number of different causes. Subtle anatomic abnormalities in the alignment of an adolescent's hips, knees, or legs can contribute to anterior knee pain. *Miserable malalignment syndrome* (MMS) is a term used to describe a triad of anatomic findings—excessive femoral anteversion (inward rotation of the knee, relative to the hip), increased knee Q angle (alignment that creates an outward pull on the kneecap by the connecting tendons), and external tibial torsion (outward rotation of the leg)—which are more frequently found in females and are associated with anterior knee pain.

Anatomy

At birth, there is a normal rotational alignment of the femurs (thighbone) and the tibias (shinbones) from top to bottom, which changes throughout the process of skeletal development. The bottom portions of both the femur, near the knee, and the tibia, near the ankle joint, begin by being rotated inward slightly, relative to the tops of the bones, and slowly rotate outward with increasing growth. When this process does not progress to a normal degree in the femur, the patient is said to have abnormally high "femoral anteversion." Notably, females normally have higher anteversion than males, which puts them at greater risk of having this abnormal condition. When this occurs too much in the tibia, the patient is said to have external tibial torsion, which can leave the feet splayed outward to some degree.

When abnormal femoral anteversion and external tibial torsion occur together, patellofemoral pain and other problems, such as patellar instability, can develop because of the effect on the Q angle of the knee. The Q angle is the angle formed by a line drawn from the anterior superior iliac spine (ASIS; a point on either side of the front of the pelvis) to the middle of the top of the patella (kneecap) and a second line drawn from the middle of the bottom of the patella to the tibial tubercle (the prominence at the top of the shinbone, which serves as the insertion of the patellar tendon). Because the knee and patella are rotated inward with femoral anteversion and the tibial tubercle is rotated outward with external tibial torsion, this combination creates an abnormally high Q angle. As a result, the patella has an abnormally high vector of force pulling it laterally to the outside of the knee.

Causes

Femoral anteversion and external tibial torsion are generally thought to be extremes of the physiologic spectrum of rotational development during skeletal maturation. Increased knee Q angle can be caused by other factors, such as a tight lateral retinaculum (connective tissue that runs from the patella to the side of the femur, along with the joint capsule) or genu valgum (knock-knees), but femoral anteversion and external tibial torsion are among the most common causes.

Symptoms

The primary symptom of MMS is patellofemoral, or anterior, knee pain. Patellar instability, in which the kneecap partially slides (subluxes) or dislocates out of its normal groove to the outside of the knee, can also occur in a small number of patients.

Diagnosis

Diagnosis of MMS is made primarily with a comprehensive physical examination focused on measuring the rotation of a patient's hips keep to assess femoral anteversion, and measuring the position of the feet relative to the knees (thigh-foot angle measurements) keep to assess tibial torsion. Evaluation of patellofemoral tracking, or the way in which the kneecap slides in its groove during knee flexion and extension, can reveal signs associated with MMS, such as patellar tilt (in which the kneecap tilts inward), or lateral subluxation. The appearance of "squinting patellas" or "patella alta" (high-appearing kneecap) is also a feature of MMS.

Full-length, standing lower extremity radiographs should be obtained to assess alignment and perform Q-angle measurements. Special techniques with computed tomography (CT) scans have been described for evaluating femoral anteversion and may have a role in preoperative planning.

Treatment

Nonsurgical Treatment

Patellofemoral knee pain is usually treated with physical therapy aimed at quadriceps strengthening and hamstring stretching. Some patients may benefit from selected patellar bracing or taping as well.

If femoral anteversion is detected before a child reaches skeletal maturity, it may spontaneously resolve as the child grows. However, external tibial torsion tends to worsen with age, so interventions should be planned with the patient's age and this natural history in mind. Braces and other devices have not been shown to be effective in treating either type of rotational deformity.

Surgery

If anterior knee pain persists despite aggressive physical therapy and the adolescent's rotational abnormalities are severe, rotational osteotomy surgery may be beneficial in select cases. Such a surgery involves making a transverse bone cut straight across either the femur or the tibia and rotating one end of the bone relative to the other, so as to improve the rotational alignment at the knee joint. A metal nail or plate and screws are used to facilitate healing of the bone in its new position.

After Surgery

When patients receive osteotomy surgery for MMS, there is generally a short period of recovery involving protection of weight bearing with crutches. An additional procedure to remove the hardware placed at the time of osteotomy may be pursued, but this is usually performed several months to years later.

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See also Femoral Anteversion (Turned-In Hips); Knee Injuries; Patellofemoral Pain Syndrome; Q Angle

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Mixed Martial Arts, Injuries in

Mixed martial arts, also known as MMA, is a hybrid system composed of several practical aspects of multiple martial arts. MMA may include cross-training in the areas of boxing, jiujitsu, karate, muay thai, wrestling, judo, and other traditional martial arts. In recent years, MMA has become more popular, rivaling the financial success and popularity of boxing. It has undergone a dramatic evolution from the early days of "no-holds-barred" fighting to a commissioned sport with weight classes, rounds, and rules. Due to the nature of MMA fighting, it plays host to numerous injuries because of its blend of ground fighting and striking. And similar to boxing, it also has its share of controversy and debate within the sports medicine community.

History

It is generally recognized that martial arts developed not in one particular place but all over the world as a means of defense or military development. MMA-style competitions can be traced back to the Olympic Games themselves, when Greek pankration was introduced in 648 BCE. Pankration was a mix of boxing and wrestling, with minimal rules. With the rise of the Roman Empire, interest in Greek pankration waned, which led to the rise of other martial arts systems. The idea of integrating well-defined, "traditional" martial arts would be up to the individual practitioner.

The idea of integration became more popularized through the art of Jeet Kune Do, created by the martial artist/actor Bruce Lee, whom many consider to be one of the early developers of the idea of MMA. Although Lee was influential in martial arts, the evolution of modern MMA did not truly begin until the Ultimate Fighting Championship (UFC) was introduced to North American audiences in 1993. Although no-holds-barred fighting events had been held for many years in other countries, they did not become popular until the UFC held its first event. The UFC was an eight-man tournament with minimal rules, no time limits, and no weight classes, pitting different martial arts against one another. The tournament winner, Royce Gracie, was a 183-pound (lb; 1 lb = 0.45 kilograms) Brazilian jiujitsu practitioner who had defeated fighters and at times outweighed the smaller fighter by as much as 100 lb. Royce Gracie would continue his success by becoming a champion again in the UFC 2 event, demonstrating the effectiveness of grappling and submission fighting. Many would argue that it was Gracie's success that motivated "striking" martial artists around the world to incorporate "ground-fighting" skills into their armamentarium to make them more complete fighters. As the UFC's popularity grew, Japan would also play host to other similar events through its Pancrase Hybrid Wrestling, Shooto, and PRIDE Fighting Championships. And as the field of MMA's popularity grew, the idea of no-holds-barred fighting was given up in North America and replaced by a new set of rules and regulations known as the Unified Rules of Mixed Martial Arts, originally commissioned by the New Jersey State Athletic Commission in 2000. By the end of the century, a new type of martial artist arose, one who would be successful by cross-training in the areas of boxing, jiujitsu, muay thai, wrestling, karate, judo, and other traditional martial arts.

Rules

Although many rules exist for MMA competition, the most commonly used are the guidelines set by the New Jersey State Athletic Commission. Below are some basic competition rules set by the commission.

- Weight classes should be maintained.
- Gloves are to be 4-, 5-, or 6-ounce (oz; 1 oz = 28.35 grams) gloves supplied by the promoter and approved by the commission.
- No Gi (traditional martial arts shirt) shoes or shirts should be used.
- Nonchampionship contests are of three rounds, each round being of 5 minutes' duration.
- Championship contests are of five rounds, each round being of 5 minutes' duration.
- All bouts are scored by three judges based on a 10-Point Must System and evaluated on the basis of effective striking, grappling, control, aggressiveness, and defense.
- Warnings are issued for holding or grabbing the fence (or ropes) and holding the opponent's shorts or gloves; penalties may result in a deduction of points or disqualification if the infractions mentioned continue.
- Basic fouls that will result in penalties include, but are not limited to, head butting, eye gouging, biting, hair pulling, fish hooking, groin attacks, strikes to the spine or the back of the head, kicking or kneeing the head of a downed fighter, throat strikes, or stomping of a grounded fighter.

Sports Medicine Issues in Mixed Martial Arts

Because of its cross-training nature, MMA practitioners are susceptible to many types of injuries. Below is a description of the more common types of injuries sustained.

Takedown Injuries

Common MMA takedown techniques include the hip toss, suplex, souplesse (a variant of the suplex), and the guillotine drop. The hip toss is generally a throw of an opponent using the hip as the fulcrum. The suplex is a technique using the back hyperextension of the technician to throw an opponent, with the souplesse differing in how much extension is performed. The guillotine drop is a type of takedown that includes first having an opponent in a front-facing choke and then having the technicians throw their legs around the opponent's body, using gravity to take down their opponent while still maintaining the choke. Due to the nature of the techniques, the suplex and souplesse techniques can lead to back hyperextension injuries such as spondylolysis or spondylolisthesis, which are commonly seen in wrestlers or gymnasts. The guillotine drop also places the neck in flexion, which, in addition to the gravity of the practitioner applying it, can lead to further cervical flexion injuries.

Head and Facial Injuries

A high proportion of MMA matches are stopped due to either head injury or facial laceration. Although traumatic brain injury has been a topic of discussion among the fighting arts, the knockout proportion is lower than in boxing. This may be the result of allowing the fighters to use a "tap out" mechanism to end the competition at any time due to a submission or strikes. The most common result of matches is actually either a technical knockout (TKO) or a tap out. Facial lacerations are the most common injury sustained in MMA competition.

Other Health Issues

Because MMA involves grappling and submission techniques, many practitioners are also susceptible, though relatively rarely, to anoxic brain damage due to frequent strangulation or to joint strains due to its manipulation for submission. Blood-borne diseases caused by human immunodeficiency virus (HIV) and hepatitis virus are also considered, as well as skin conditions such as tinea and herpes gladiatorum.

Ergogenic Aids

Ergogenic aids, or supplement enhancers, have been an issue for many athletes. Steroid supplements have been the most popular enhancer for MMA practitioners, with claims of maximizing the response to resistance training, improving the immune system, and increasing fat metabolism. Although there are numerous anecdotal claims for their use, steroids have not been scientifically shown to improve athletic performance.

Ethical Considerations: Should MMA Be Banned?

The British Medical Association calls for a complete ban on MMA on the grounds of what it characterizes as excessively violent behavior. Many comparisons have been made with boxing, which is banned in many countries, including Norway, Iceland, and North Korea. As a comparison, there have been two documented deaths in MMA competition (one sanctioned, one nonsanctioned), whereas at least 140 boxers worldwide have died since 1990. Some of the counterarguments to banning both boxing and MMA are that freedom of choice should not be denied, training develops discipline, and, as a whole, boxing and MMA are safer today due to stricter rules and regulations. Another contentious issue is the participation of children, which recently has been fueled by allowing children to take part in MMA competitions (with protective headgear). These issues will continue to be a part of any full-contact, fighting-based competition.

Arnold E. Cuenca

See also Contusions (Bruises); Craniofacial Injuries; Knee Injuries; Nose Injuries

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Morton Neuroma

A *Morton neuroma,* also known as an *interdigital neuroma,* is a benign enlargement of a nerve in the foot, most likely caused by repetitive irritation of the nerve, which can lead to pain, a burning sensation, numbness, and/or tingling in the foot and toes. It classically occurs between the third and fourth toes (the area known as the third web space of the foot), but also may occasionally form between the second and third toes (the second web space). It is a common condition in athletes, especially those who wear restrictive footwear for their sport (e.g., ballet dancers) or those involved in high-impact activities (e.g., distance runners).

Anatomy

Two main nerves are responsible for sensation in the sole of the foot: the medial and lateral plantar nerves, both of which originate from the tibial nerve in the leg. The medial plantar nerve supplies sensation to the first, second, and third toes, as well as part of the fourth toe; the lateral plantar nerve supplies sensation to the fifth toe and part of the fourth toe. Branches from these nerves run in between the metatarsals in the web spaces of the foot; for this reason, they are also called the interdigital nerves. The branches from the medial plantar nerve run in between the metatarsals in the first and second web spaces; the branches from the lateral plantar nerve run in between the metatarsals in the fourth and fifth web spaces. In the third web space, a branch from the medial plantar nerve and a branch from the lateral plantar nerve join together, and the combination then runs between the third and fourth metatarsals. Due to this confluence of nerves, there is believed to be an increase in the thickness of the nerve branch that runs in the third web space; this may play a role in this location being the most common site of occurrence of Morton neuroma (see Figure 1).

Pathology

A Morton neuroma is a benign outgrowth of one of the branches of the medial or lateral plantar nerves. This outgrowth is due to perineural fibrosis—the formation of fibrous tissue around the nerve itself; it is not, in fact, a tumor of nerve cells, as the name *neuroma* would indicate. The perineural fibrosis in Morton neuroma occurs in response to repetitive trauma and/or stress to the nerve. A number of factors have been found to contribute to the increased susceptibility of the interdigital nerves to this fibrosis. Due to the limited space

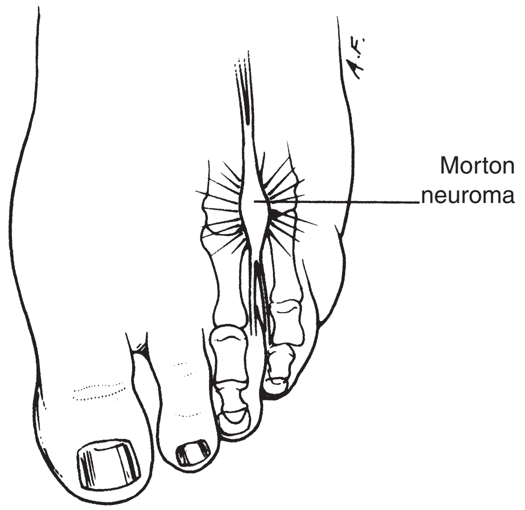

Figure 1 Morton Neuroma

Note: This benign outgrowth of a branch of the medial or lateral plantar nerve is a response to stress or repetitive trauma to the nerve.

between the metatarsal heads, the nerves are vulnerable to compression at that point; this effect is heightened by shoes with a small toe box, which further decreases the space between the metatarsals. Additionally, the interdigital nerves travel over a ligament that runs between the metatarsals, and during ambulation, the nerve can be pressed against this structure; specific foot types (pronated and pes planus) exaggerate this effect. Furthermore, in the third web space, branches of the medial and lateral plantar nerves join together near a muscle of the foot (the flexor digitorum brevis) and are therefore exposed to increased pulling forces when the toes are extended (dorsiflexed), as occurs during walking. Finally, the fourth metatarsal has more mobility than the third; this may result in the interdigital nerve becoming wedged against the third metatarsal and being subjected to repeated pressure from the fourth metatarsal as it moves with ambulation.

Certain foot types may also be predisposed to the formation of Morton neuroma. As noted briefly, both pronated and pes planus foot types increase the forces from the flexor digitorum brevis muscle on the interdigital nerve in the third web space and can thus elicit irritation in that nerve. Additionally, any abnormal positioning of the toes, including bunions (hallux valgus deformity) and the hammertoe deformity, may alter the distance between the metatarsal heads and, thereby, increase the likelihood of Morton neuroma formation.

The restrictive footwear used in some sports, especially ballet, decreases the distance between the metatarsal heads and can lead to nerve compression. Furthermore, athletes who are involved in sports that invoke repetitive trauma on the foot or excessive extension/dorsiflexion of the toes are especially prone to the development of Morton neuroma; examples of these sports are running, basketball, ballet, and racquet sports.

Due to all of these factors, the interdigital nerves can be exposed to repetitive trauma, which leads to irritation and inflammation of the nerve. This continued irritation then initiates the process of perineural fibrosis. Once the nerve starts to fibrose, it enlarges in size, which amplifies its susceptibility to irritation, thus creating a cycle of worsening irritation and fibrosis.

Symptoms

The nerve irritation that is the hallmark of Morton neuroma can manifest in a number of different symptoms. Pain in the sole of the forefoot is common and, once the condition has advanced significantly, is often described as similar to the feeling of walking on a marble. Alternately, there may be the feeling of burning, cramping, or numbness and/or tingling in the forefoot. All of these symptoms may radiate down into the toes as well. Symptoms are typically made worse with walking, especially on hard surfaces and while wearing tight shoes or high heels; conversely, symptoms often improve with cessation of walking, removal of the tight or high-heeled shoe, and massage of the affected area.

Initially, the symptoms only occur intermittently, with even weeks to months between episodes, and are mild. However, with the progression of neuroma formation, the symptoms occur more often and last for longer periods; they may become continual once the damage is severe enough.

Epidemiology

Morton neuromas are of significantly higher prevalence in women than in men. The vast majority occur in people 15 to 50 years old; however, patients either younger or older than this may also develop one. The most common site for a Morton neuroma is in between the third and fourth metatarsals (third web space); about 80% to 85% of these injuries occur in this location The remaining 15% to 20% occur in between the second and third metatarsals (second web space). Morton neuromas do not occur in the first or fifth web spaces.

Diagnosis

A careful history of the symptoms and physical examination of the foot are the mainstays of Morton neuroma diagnosis. As occasionally a patient with Morton neuroma may not have any findings on physical exam, a description of the symptoms outlined above can be enough to make the diagnosis. In general, the diagnosis of Morton neuroma does not need any confirmatory imaging studies such as an X-ray or magnetic resonance imaging (MRI).

A number of physical exam findings have been associated with Morton neuroma. The two most common findings are tenderness with palpation of the web space that is affected and pain with horizontal compression of the forefoot, also known as the "squeeze test." In some instances, a painful "click" underneath the affected web space may be felt and heard by the examiner during the squeeze test; this is known as a *Mulder sign,* or *Mulder click,* and is thought to be due to the enlarged area of the affected nerve passing over a ligament.

Additional findings may include a decrease in sensation in the involved web space and toes and reproduction of the patient's symptoms with extension (dorsiflexion) of the toes.

Treatment

The initial approach to treatment of Morton neuroma is to take steps to lessen the nerve irritation, including shoe modification, adjustment of activity, and oral anti-inflammatory medications. Shoes with a wide toebox help decrease the compression of the interdigital nerve by the metatarsal heads; furthermore, the placement of a metatarsal pad in the shoe can increase the space between the metatarsal heads. In instances where the patient has a foot type that may contribute to the development of Morton neuroma (as in pes planus or pronated foot type), custom orthotics may be of benefit. Additionally, activities that expose the foot to repetitive trauma, such as prolonged running or jumping, should be avoided for a period of time until the nerve inflammation subsides. Finally, a course of oral nonsteroidal anti-inflammatory drugs (NSAIDs) may be tried as well.

The success rate of these conservative measures has not been satisfactorily established in the literature, but a general approximation is that about 20% to 30% get complete or acceptable relief. This proportion of success decreases with the length of time of the patient's symptoms.

If these interventions fail to provide adequate relief, an injection of the combination of a local anesthetic and a corticosteroid into the affected web space has been shown to be effective in decreasing symptoms in some cases.

Occasionally, all of these therapies may not sufficiently mitigate the symptoms of Morton neuroma. In these cases, surgical excision of the neuroma has been shown to have about an 80% rate of success in the relief of symptoms. However, the patient is left with a permanent loss of sensation in the area supplied by the affected nerve.

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See also Athletic Shoe Selection; Dance Injuries and Dance Medicine; Flat Feet (Pes Planus); Foot and Ankle Injuries, Surgery for; Metatarsalgia; Orthotics; Overpronating Foot

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Motivation

The word *motivation* comes from the Latin word for "to move." In other words, motivation means to get something or someone from one place to another. Motivation is essential in achieving one's goal, no matter how near or far-reaching. One area of life during which motivation plays a more obvious role is sports and athletic participation. Athletes, young and old, amateur and professional, require something to get them to that next place. Motivation is what gets the couch potato off the couch and into the gym. It provides the incentive for the high school athlete to work toward an athletic scholarship. Motivation helps the injured, professional athlete do what is necessary to recover completely and return to the field of play. Motivation has social benefits as well, including increased self-esteem, improved academic achievement, and decreased high-risk youth behaviors and school attrition. This entry discusses the process of providing healthy motivation to athletes as they strive to achieve their goals.

Motivation is not one moment in time. It does not suddenly come to an individual aspiring to athletic success. Motivation is a process. Although motivated and positive coaches, parents, family, friends, and fellow athletes are important, most of the motivation process comes from within the athlete.

The Motivation Process

Define a Vision

The motivation process consists of three basic parts. The athlete must first define his or her vision. An athlete's vision answers the question of why participating in that sport or learning that new skill is important. A vision provides a picture of the "after" and the inspiration to attain it. In creating a vision, an athlete must first focus on what he or she wants (i.e., I want to improve my fitness level), instead of on what he or she does not want (i.e., I do not want to get hurt while running). The vision should be something the athlete feels passionate about and truly wants for himself or herself. The vision should be as specific and detailed as possible. As the process of determining what he or she may truly want and feel passionate about can be difficult, athletes should allow time to define their vision.

Determine the Current Level

Once an athlete has defined his or her vision, the next step is to determine his or her current standing in relationship to that vision. To move someone or something from one place to another, there must be a starting point from which to determine the necessary distance and effort it will take to achieve the goal. This step requires a realistic assessment of the athlete's physical and mental strengths and weaknesses. It is essential that the athlete remain positive and constructive during this process.

Determine Methods for Achieving Goals

Once an athlete has a vision and understands his or her current level in relation to achieving that vision, he or she must determine how to move toward that vision. Just as defining the vision and assessing the current level can take time, this "how to" process can also be challenging and can be divided into two general parts: specific goal setting and focusing.

When beginning a cross-country driving trip, we often break down our drive into shorter segments (e.g., state by state, 200 miles [mi; 1 mi = 1.60 kilometers] driving and then rest), so as to quiet the sometimes silent question, "Are we there yet?" Staying motivated to achieve an athletic vision also includes the creation of short-term, intermediate-term, and long-term goals. Goals can be divided into four general categories: athletic/physical, academic/professional, social, and spiritual. These goals should be identifiable and realistic, in addition to being challenging. Goals should be performance related (e.g., running a mile without walking) instead of result based (e.g., running a mile in 8 minutes). Athletes should periodically reevaluate their goals and reassess their progress toward their vision. Frequent feedback and positive reinforcement, such as a review of recent past successes, can keep an athlete on track to achieve his or her vision.

Good mental skills are also important in achieving an athlete's vision. One important mental skill is focusing, in which an athlete should concentrate on things within his or her control. For example, the athlete should concentrate on skill and fitness development, instead of on the chance that it might rain during his or her run. In general, we tend to move toward that on which we focus, so it is important that our focus be not only something we can control but also something positive. Another important aspect of focus is maintaining it. This maintenance may include remaining in the moment (e.g., thinking about one's form during a run instead of about one's upcoming project deadline) or persevering despite adversity (e.g., continuing to play despite an earlier disappointing performance). To keep their focus, athletes can ask themselves a few basic questions about their current activity, whether their thoughts support that current activity, and whether their thoughts are about something they can control.

Other mental skills useful in achieving an athlete's vision include self-talk, mental imagery, and relaxation. Self-talk should always be positive, with a focus on the athlete's strengths and possibilities. Each affirmation should be brief and easy to repeat; thus, the athlete can retrieve these positive thoughts quickly and easily during practice or competition. Mental imagery involves creating an image of the athlete's vision and/or short-term goals (e.g., a new skill) and using all of his or her senses to imagine performing that new skill correctly from beginning to end. For example, a platform diver might imagine the smell of the pool, the coolness of the air on his or her skin, the view from high above the ground, and the quietness associated with that high perch. To be effective, mental imagery should be performed in a quiet place free from distraction (internal and external), should be practiced regularly, and should be positive. As the athlete becomes more adept at mental imagery, he or she may be able to increase the complexity of his or her imagery sessions (e.g., from a skill to a set of skills to a whole performance). With all of the activity, physical and mental, involved in achieving an athlete's vision, the athlete must also learn to relax. This type of relaxation does not refer to reclining by the pool with an iced drink. This relaxation involves using only those muscles necessary to perform a particular skill. This relaxation ability stems from an increased ability to perform the skill, as well as an increased ability to use imagery and focus. This can be seen in the simple example of handwriting. When first learning to write, children often hunch over their desks with a death grip on their pencils, making faces as they practice writing their letters. Adult writing appears to be effortless, with only those muscles necessary to keep the pen on the paper and make the words legible being moved. Adults have mastered the skill of relaxation while writing. Athletes work to master the skill of relaxation while achieving their vision.

Summary

Motivation can affect an athlete's participation in a sport, as well as the quality of that participation, whether in the initial stages of training, at the elite levels, or in recovery. It can also improve an individual's mental fitness and behavior. The process of motivation includes defining a vision, determining the current level of skill in relation to the vision, and determining the methods for achieving that vision. Athletes should set challenging and realistic goals, think optimistically, reinforce positive behavior patterns, and obtain frequent constructive feedback. Using the mental skills of imagery, focus, and relaxation can help them reach their goals.

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See also Benefits of Exercise and Sports; Conditioning; Exercise Programs; Gender and Age Differences in Response to Training; Mental Health Benefits of Sports and Exercise; Principles of Training; Weight Gain for Sports; Weight Loss for Sports

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Mountain Bike Racing, Injuries in

Mountain bike racing takes place at Olympic, collegiate, professional, and community levels. It involves a wide variety of race styles and bike designs. Mountain bike races often take place in rural areas and place unique demands on emergency services due to increases in local emergency department visits and the challenges of transporting injured athletes from remote areas. Athletes expect race organizers to have a plan for providing medical assistance to the injured racers. Basic knowledge of equipment, competition demands, and common injuries in mountain bike racing is crucial for medical personnel in charge of race coverage. This information is also important to physicians and allied health care providers who take care of these athletes in their outpatient practices.

The Mountain Bike

A mountain bike is designed for off-road use. Mountain bikes were invented in the 1970s in northern California. Mountain bikes are designed to ride on rough and varied terrain. Compared with road bikes, mountain bikes have a more upright riding posture, wider tires with an aggressive tread, and beefier frames. The modern mountain bike has evolved to suit the different styles of riding. In general, mountain bike design attempts to strike a balance between terrain handling and pedaling efficiency. Bikes designed for more difficult terrain will be heavier, with geometries and suspension systems that make them less efficient at transferring pedaling effort into forward motion. Mountain bikes designed for cross-country racing will be lighter but less forgiving in difficult terrain.

Demographics of Mountain Bike Racing

Mountain biking has seen a rapid rise in popularity and economic importance in the past 20 years. Mountain biking is now a widespread activity most popular in the west and north central United States. As interest in mountain biking as recreation has increased, so has participation in mountain bike racing. By 2000, almost 1 million U.S. adults had participated in a mountain bike race. The most rapid increase has been in the participation in community races. The vast majority of racers are men in their 20s and 30s; however, participation of women in racing is also increasing. Notably, the riders in community races tend to be older and female (both risk factors for injury) compared with other forms of racing.

Classifications of Mountain Bike Racing

With the variety in disciplines and levels of competition, the taxonomy of mountain bike racing remains elusive. Mountain bike racing achieved full Olympic status in 1996 when the first medals were handed out in Atlanta. It is also a collegiate sport administered by the National Collegiate Athletic Association (NCAA) with competition and national championships at the Division 1 and 2 levels. The National Off Road Biking Association (NORBA) holds yearly national championships at the professional, collegiate, masters, and junior levels. At the 2006 NORBA national championships, race categories included the following:

Cross-country: a mass start race over varied terrain that averages about 48 kilometers (km) or 30 miles (mi)

Downhill: gravity-assisted time trial event that lasts about 10 minutes

Short track: groups of riders repetitively completing short loops for about 30 minutes

Mountain cross: small groups of riders competing on a gravity-assisted course

Marathon: mass start point-to-point races of 60 to 100 km

Cross-Country Racing

Cross-country racing deserves special mention. This type of racing closely mimics recreational trail riding. It is the most established style of racing and almost the exclusive form of community racing. Cross-country races are typically mass start events with start position determined by expected finish time. The race can be a point-to-point or a repeated-loop–style course. The terrain is often varied, including sharp ascents, descents, and occasional technical sections. Cross-country races vary in distance but usually are about 30 mi (48 km). The duration of the race varies greatly depending on the skill of the rider and the terrain. A typical finishing time could range from 1.5 to 4 hours. Cross-country style races place unique physiologic demands on the riders. Due to the diversity of terrain, race duration, and need for frequent changes in riding positions, these races require a mix of aerobic endurance, anaerobic power, and muscular strength. Technical skill and strategy also become important in high-level competition.

Injury Epidemiology

Injuries are common in mountain biking. The cause of injuries can be rider related, such as errors in judgment or technique, riding beyond one's ability, intoxication, or lack of a helmet. They can also be bike related and caused by mechanical failure or improper bike fit. Terrain-related risks have also been identified, including unfamiliarity, downhill sections, and unique surfaces such as soft sand or wet, slippery conditions. Data show that a fall over the handlebars poses the great risk of serious injury. Admirably, the mountain biking literature shows a very high use of helmets compared with other cyclists and a corresponding decrease in serious head injuries.

As a whole, mountain biking is thought to be responsible for 10 million injuries per year. Surveys of riders reveal that the vast majority had been injured in the previous year. Most of these injuries would be considered minor; however, about 20% of riders reported a significant injury in the last year. Despite the high rate of injuries in those who participate in mountain biking, the rates of significant injury in competition are actually quite low (0.45%–0.6% in cross-country races).

Some studies suggest that advancing age is a risk factor for injury. The literature also repeatedly shows that women are at greater risk of injury than are men. The reason remains unclear, but suggested explanations include less experience or general gender-related physiologic differences, such as lesser upper body strength. In general, studies suggest that experience does not preclude injury. Rather, injuries increased with increased exposure; that is, the more you ride the more likely you are to get injured. And riders who race have a fourfold increased injury rate per year. This suggests that competitive, experienced women riders are at the greatest risk for significant injury.

Types of Specific Mountain Biking Injuries

Acute Traumatic Injuries

Blunt and penetrating trauma make up the vast majority of injuries seen in mountain bike racing. Skin and soft tissue abrasions, contusion, and laceration are ubiquitous. Fractures represent the second most common type of injury observed during racing. Most fractures are noted in the upper extremity, with clavicle fractures being the clear leader. However, rare lower extremity, trunk, pelvic, and cervical fractures have been reported. Joint injuries are also frequently seen, particularly sprains of the acromioclavicular joint, wrist, and knee. Injuries to the head and face are notable for a high rate of concussion (3–13% of injuries in some studies) and dentoalveolar trauma. Trauma to the abdomen and chest poses unique risks, including rib fractures and injury of the internal organs. Curved handlebar ends have been implicated as an increased risk for abdominal injury. Genital injuries can result from forceful straddling of the top tube, causing lacerations and blunt trauma. Fatalities are rare, especially when compared with road biking.

Overuse Injuries

Survey-based studies show that 45% to 90% of respondents had experienced overuse injuries due to mountain biking. Hand and wrist, neck, low back, knee, and genitourinary complaints were all common. Causative factors include excessive training, bike fit, technique, and terrain.

Environmental Injuries

Races often take place in rugged areas, where quick changes in the weather are common, leading to concerns about hyperthermia, hypothermia, and frostbite, depending on the conditions. High altitudes, exposure, and long race durations increase the risk of clinically significant sunburn. Altitude-related illness is often a concern as many races take place at clinically significant elevations. An extreme example is the renowned Leadville, Colorado, mountain bike race that covers 100 mi

(160.9 km), all between 10,000 and 12,000 feet (3048–3657.6 meters).

Medical Illnesses

Although most racers are healthy, some may have underlying medical problems that present as acute emergencies during a race, including asthma, heart disease, diabetes, and allergies. There are also specific medical illnesses that are potentially induced by mountain bike racing, including dehydration, hyponatremia, and rhabdomyolysis.

Prevention of Injury

General evidence-based recommendations to prevent injury in mountain bike racing include wearing of a helmet, familiarization with the course, mechanical bike check prior to the race, and evaluation to ensure proper bike fit. Riders would also likely benefit from a mountain bike skills–development program and fitness program that encourages upper body strength and endurance training for women.

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See also Biking, Injuries in

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MOUTHGUARDS

Mouthguards are pliable plastic devices used in sports to protect the oral cavity, including the lips, teeth, jaw, and gums. Mouthguards are also known as gum shields, mouth protectors, and mouth shields. Mouthguards are used to avoid and reduce trauma to the mouth during collision sports, such as American football, boxing, rugby, lacrosse, and ice hockey, and during contact sports, such as basketball and soccer.

Injuries

The risk of injury is greater in collision sports than in contact sports. Oral cavity trauma is not life threatening, but associated maxillofacial injuries and fractures can compromise the airway. Soft tissue injuries include cuts and lacerations of the lip and tongue. Swelling of gums and other oral parts is also associated with collision sport trauma. Almost 80% of dental injuries are to maxillary teeth, the most frequent injury being crown fractures of the central incisor teeth, usually affecting a single tooth. Chipping, cracking, fracturing, or displacement of teeth is possible, as well as teeth being knocked out by falls or collisions with another player or object. Tooth injury varies in degree and type with age. In children, the primary teeth are commonly displaced, whereas in adults, the permanent teeth are often fractured. In children, injury usually results in primary teeth failing to continue eruption or in color changes, infection, abscess, loss of space in the dental arch, ankylosis, injury to the permanent teeth, and/or abnormal exfoliation. In the case of permanent teeth, the injury can result in discoloration, infection, abscess, loss of space in the dental arch, ankylosis, reabsorption of root structure, and/or abnormal tooth development.

Causes

The common cause of oral injury is severe impact to the mouth and teeth. This can be the result of a fall, collision with a fellow player, or collision with sports equipment and hard objects (stick or ball). The damage can be sufficient to cause lacerations of the lip and disruption of the enamel and/or dentin of a tooth.

Prevention

Mouthguards reduce the risk of broken or lost teeth and other jaw and mouth injuries during contact sports by cushioning a blow to the face that otherwise might result in an oral injury. A mouthguard decreases the intensity of force to the mouth during a powerful collision, which can cause injury to the lips, cheek lining, tongue, alveolar arches, and teeth. A misdirected elbow in a one-on-one basketball game or a fall from a bicycle (noncontact) can result in chipped or broken teeth, nerve damage to a tooth, or even tooth loss. A mouth protector can reduce the risk of such injuries as well as protect the soft tissues of the tongue, lips, and cheek lining. Mouthguards have also been shown to reduce the risk of mandibular fracture and brain injury.

Types

Three types of mouthguards are available.

Over the Counter. These mouthguards, which are readily available at most sporting goods stores, are inexpensive but come only in limited sizes (small, medium, large). They are ready-made and require no preparation; simply remove from the cover and put in the mouth. Over-the-counter mouthguards are often bulky and lack any retention; they need to be held in place by constantly biting down. The bulky mouthguard may interfere with breathing and talking, making them the least comfortable type. The athlete usually tries to alter or even cut this mouth shield in order to make it more comfortable. This decreases the protectiveness of the mouthguard. The lack of retention and protection makes these mouthguards the least recommended.

Boil and Bite/Mouth Formed. These mouthguards are also readily available in sporting goods stores and are inexpensive. They are most frequently used because of better fit than over-the-counter mouthguards. These mouthguards are made from a thermoplastic material that is softened by immersion in boiling water and then adapted to the mouth by using finger, tongue, and biting pressure. A good fit can be achieved if the instructions are followed with care. Otherwise, one can end up with an ill-fitting mouthguard. However, mouth-formed devices are available only in limited sizes. They sometimes lack proper extensions and do not cover the posterior teeth.

Custom. These mouthguards are made by a dentist; as is the case with many custom-made items, they are expensive. Custom mouthguards are well adapted to individual mouth shapes, have greater retention, and are comfortable. They have no effect on breathing and hardly interfere with talking. The dentist takes many issues into consideration to ensure a proper fit of the mouthguard. The aspects addressed are the sport being played, the age of the athlete, the compliance of the mouthguard with the sport, and any other dental conditions particular to the athlete, such as cavities or missing teeth.

There are two categories of custom mouth guards: vacuum mouthguard and pressure-laminated mouthguard. The vacuum mouthguards are made from stone casts of the athlete's mouth using an impression made by a dentist. A thermoplastic mouthguard material is tailored over the cast with a special vacuum machine. The pressure-laminated mouthguard consists of multiple layers that are chemically fused together under high heat and pressure. The multiple layers make this second category more protective.

Mouth Guard Care

The following precautions should be taken:

- Brush the mouthguard after every use. Washing with mouthwash is also recommended.
- Frequently used mouthguards should be washed with a solution of soap and water once a week.
- Store the mouthguard in a container that lets air in.
- Do not expose the mouthguard to sunlight and heat as these can alter the mouthguard's shape and, therefore, reduce its protective power.

- Replace the mouthguard if it has tears, holes, or fraying.
- Children need regular checkups to see if refitting is required.

Recommendations

The use of mouthguards in sports is highly recommended by dentists and experts to avoid oral/facial injury. It should be noted that 10% of sports injuries are on the face and mouth. Mouthguards help avoid and reduce the severity of trauma. In sports, both collision and contact, at both professional and recreational levels, mouthguards are adapted for use to prevent injury to the anterior teeth and parts of the face and jaw. Mouthguards also help protect the athlete from concussions. The use of mouthguards is especially recommended in people who wear braces because mouth trauma can damage orthodontic brackets or other fixed appliances; a properly fitted mouthguard may be particularly important for people who wear braces or have fixed bridge work.

Syeda Alena Fatima

See also Concussion; Craniofacial Injuries; Dental Injuries; Protective Equipment in Sports

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Muscle Cramps

A muscle cramp is considered a minor heat-related illness, but the athlete or exerciser who is experiencing one would argue that this involuntary muscle spasm is anything but minor. Cramps are very common and very painful among both elite and recreational athletes, and they are most likely to occur in hot, humid weather conditions.

For most people, a cramp is not a long-term problem. It usually subsides within a few minutes but may recur several times during an event after the initial muscle spasm has disappeared. Although a cramp can affect any muscle or muscle group, more than 90% of them involve the quadriceps (the muscles on top of the upper legs), hamstrings (the muscles behind the upper legs), or calves (backside, lower leg muscles). According to the American Academy of Orthopaedic Surgeons, muscles that span two joints are the most prone to cramping.

On rare occasions, muscle cramps may be an indication of a more serious problem associated with blood circulation, the nervous system, body metabolism, hormonal imbalance, or medications. The person who has severe cramps, frequent cramps, or cramps that do not respond to simple, conservative treatments should see a physician.

Causes

There are several theories regarding the exact cause of cramps but very little absolute proof. Physicians, trainers, researchers, and exercise scientists generally agree that cramps are likely to involve a combination of factors and that they may occur in different people for different reasons. Among the possible causes are muscle fatigue, vigorous exercise (especially in hot, humid conditions), exercising while in poor physical condition, dehydration, and dietary deficiencies, including not enough salt intake. “Salty sweating,” according to one prominent sports medicine physician, seems to be the common denominator for all exercise-related cramps.

A common scenario for developing a cramp would be: (a) a football player, (b) early in the season, (c) playing in hot weather, (d) late in a game or practice session, (e) not acclimatized to playing conditions, and (f) not well hydrated during the period leading up to the event. A similar combination of factors could happen in tennis, soccer, lacrosse, basketball (in gyms that are not air-conditioned), or long-distance running events, among others.

Symptoms

The most common symptom of a cramp is also the definition—a sudden, involuntary contraction or spasm of a muscle. A hard knot of muscle tissue may be palpable or visible beneath the skin, and as any athlete who has had a cramp can attest, the muscle spasm causes extreme pain.

Treatment

Cramps usually subside without medical attention, but there are steps the athlete can take to deal with the immediate crisis. First, stop the activity that triggers the cramp, which is something that usually happens anyway. Continuing the activity may simply be impossible.

If the athlete is alone, self-treatment is almost as involuntary as the injury. Quickly massage, squeeze, or put pressure on the muscle until it relaxes. Gently stretching the muscle or muscle group might also relax the muscle and relieve the pain. For a quadriceps spasm, pull the toes and the forward part of the foot back toward the shin. For a cramp in the calf, try putting the weight of the body on the affected leg and slightly bending the knee.

If a cramp recurs for a period of several days, apply cold packs for 15 to 20 minutes, three to four times a day. If the muscle still feels tight, use moist heat or take warm baths for 20 to 30 minutes at a time, three to four times a day.

Prevention

There are no guarantees that any single measure will prevent cramps, but all of the suggestions that follow may lower the risk.

- Warm up before stretching. Muscles that are overstretched before body temperature has been raised are vulnerable to cramps and other sports-related injuries. Pay particular attention to quadriceps, hamstrings, and calf muscles. Do not stretch to the point of pain or bounce during a stretch.
- An increasing body of evidence shows that the best stretches for performance (but not necessarily related to cramps) are those dynamic movements that mimic the actions taken in a sport—not traditional, static stretches in which the muscle is stretched and held for 20 seconds or more.
- Cool down after intensive exercise sessions. Walking several hundred yards after running and slowly swimming one or two laps after a swim event are examples of cooldowns.
- Follow these hydration and acclimatization guidelines:
    - Drink a sports beverage that contains 6% to 8% carbohydrate and small amounts of sodium (110 milligrams [mg]/8 ounces [oz]; 1 oz = 28.35 grams) and other electrolytes (potassium and chloride) to prepare for intense or long training sessions.
    - Drink 10 to 16 oz (two cups; 1 oz = 29.57 ml) of cold fluid approximately 15 to 30 minutes before practice sessions or athletic events.
    - Drink 4 to 8 oz of cold fluid during exercise bouts every 10 to 15 minutes.
    - Use a trial-and-error strategy with cold fluids during periods of training to find the type of drink and quantities that work for you. Do not wait until the day before or day of an event to find out.
    - If possible, allow 1 or 2 weeks for acclimatization to the competitive environment.

Jim Brown

See also Nutrition and Hydration; Pregame Meal; Running Injuries

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Musculoskeletal Tests, Ankle

The ankle is one of the most commonly injured joints in the body, especially with activities involving jumping or running. Ankle sprains are the most common sports-related injury seen in physicians' offices. They can pose a problem because many individuals incur permanent ligament laxity and recurrent sprains and may acquire residual symptoms of pain, swelling, weakness, and decreased proprioception (joint position sense). Any of these symptoms may affect an athlete's sports performance.

The ankle joint acts as a hinge between the foot and the lower leg and functions to help propel the body in addition to providing support and shock absorption. Problems arising in the ankle can create biomechanical deviations during gait, which may cause other maladies to develop in the joints above and below the ankle. As such, tendon problems can occur around the ankle since sports activities involve high motion and stresses. With trauma at the extremities from falls and sprains, fractures in the bones of the ankle can also occur.

Examination of the patient's past history is important in establishing the nature of the ankle injury. The clinician should ask the patient about the onset of symptoms and his or her chief complaint, which may include pain, instability, weakness, or loss of range of motion. The mechanism of injury is particularly valuable in determining the injury. Patients should report any prior history of ankle injuries or disorders and what type of treatment or rehabilitation they received. The most common ankle injury is lateral ankle sprains. Usually, this involves a rolling mechanism inward of the foot and ankle, followed by immediate pain and swelling. The athlete may or may not be able to weight bear depending on the degree of the injury. If the athlete cannot weight bear, there is a greater chance that the athlete may have a fracture in the ankle or foot. Following an initial sprain, many patients will go on to have repetitive ankle sprains and will commonly complain of ankle weakness and giving out.

Acute ankle sprain

Source: University of California, San Francisco, Sports Medicine.

Examination of the Ankle

Examination of the ankle should also include a thorough evaluation of the foot (see the entry Musculoskeletal Tests, Foot). When the patient enters the room, the clinician should evaluate his or her gait pattern, standing posture, and the wear on the soles of his or her shoes. The clinician should assess the ankle for any gross deformity, malalignment, or atrophy. Acute injuries to the ankle commonly result in swelling and the development of ecchymosis. Accumulation of swelling occurs around the lateral and/or medial malleoli, in addition to moving distally into the foot.

Palpation

Palpation of the ankle is important in identifying which structure is injured. Bony structures to palpate should include the shaft of the tibia and fibula traveling down to the borders of the medial and lateral malleoli. Palpation of the neck and dome of the talus can be performed by inverting and everting the foot while palpating just anterior to the medial and lateral malleoli. Soft tissue palpation should include the ligamentous structures: the anterior talofibular ligament, posterior talofibular ligament, calcaneofibular ligament, deltoid ligament complex, and anterior tibiofibular syndesmosis. The clinician should also palpate the muscle tendons that cross the ankle joint. The peroneus longus and brevis tendon are palpable as they pass posterior to the lateral malleolus and as they course below the distal pole of the lateral malleolus toward the base of the fifth metatarsal. On the medial aspect of the ankle, the clinician should palpate "Tom, Dick, and Harry," which is a mnemonic for the posterior tibialis, flexor digitorum longus, and flexor hallucis longus. These three tendons pass posterior to the medial malleolus; the posterior tibial artery and nerve can also be palpated here. Along the anterior aspect of the ankle, the body and tendon of the tibialis anterior, extensor hallucis longus, and extensor digitorum longus can be palpated.

Specifically following an acute sprain, if the athlete is unable to weight bear four steps due to pain, the Ottawa Ankle Rules for getting an X-ray for the ankle apply. The rules indicate that if there is tenderness that is elicited on palpation over the distal 10 centimeters (cm) of the lateral or medial malleolus, then an X-ray of the ankle is indicated. These areas are typically where an ankle fracture would occur following an inversion injury of the ankle. Studies demonstrate that using the Ottawa Ankle Rules properly identifies all fractures in those locations and helps avoid taking unnecessary X-rays in the emergency room.

Range of Motion

Assessment for ankle range of motion typically begins by evaluating active, passive, and then resistive range of motion. For the ankle, there are four motions that occur at the ankle joint: dorsiflexion, plantarflexion, inversion, and eversion. To assess the passive range of motion, the patient should be seated with his or her foot off the exam table. While stabilizing the lower leg, the clinician passively applies pressure to assess soft tissue mobility. Range of motion should always be compared bilaterally, and any deficits should be noted. The normal motion for passive dorsiflexion is 10° to 15°; for plantarflexion, 50° to 70°; for inversion, approximately 40°; and for eversion, around 10°. Pain during passive movement may be musculotendinous or ligamentous. Motion may be limited due to pain, swelling, or scar tissue from a chronic injury. Finally, resistive range of motion should be conducted to assess for any muscular weaknesses or injuries.

Special Tests

Talar Tilt Test

The talar tilt test is a ligamentous stress test that examines the integrity of the lateral ankle ligaments, primarily the calcaneofibular ligament.

Description of the Maneuver. With the patient seated, knee bent, and foot in neutral or slightly dorsiflexed position, the clinician stabilizes the distal tibia with one hand while applying an inversion force to the foot.

Positive Findings. There is pain or increased joint laxity in the involved ankle. Pain may be over the calcaneofibular ligament or the anterior talofibular ligament, depending on the positioning of the ankle.

Talar tilt test

Source: University of California, San Francisco, Sports Medicine.

How good is the test? No studies have examined the validity of the talar tilt test.

Anterior Drawer Test

The anterior drawer test is a test used to examine the integrity of the anterior talofibular ligament, which is frequently injured during an inversion ankle sprain.

Description of the Maneuver. The patient should be seated with his or her knee bent, and the ankle should be typically in the neutral position at 0° or 90° to the leg. The clinician stabilizes the distal tibia with one hand while grasping the heel with the other hand and applying an anterior force to the heel. This test should be performed bilaterally to compare for differences in anterior translation.

Anterior drawer test

Source: University of California, San Francisco, Sports Medicine.

Positive Findings. Pain or increased joint laxity in the injured ankle indicates disruption of the anterior talofibular ligament. Visually, a dimple may be seen by the clinician while performing this test.

How Good Is the Test? The validity testing demonstrates the anterior drawer test to have high sensitivity, moderate specificity, high positive predictive value, and moderate negative predictive value.

Special Tips for Improving Accuracy. The examiner's index finger can be placed behind the heel with the thumb over the front of the ankle to better feel the translation of the foot in relation to the lower leg. A firm, steady load during testing can be more sensitive than a higher, quick load.

External Rotation or Kleiger Test

The test was first described by Barnard Kleiger and is used to identify syndesmotic injuries.

Description of the Maneuver. The patient is seated with his or her knee bent on an exam table. The clinician stabilizes the distal tibia while externally rotating the foot.

Positive Findings. Pain in the anterolateral ankle joint is felt, or there is an increased external rotation

External rotation test

Source: University of California, San Francisco, Sports Medicine.

of the foot when compared bilaterally. External rotation of the talus applies pressure to the lateral malleolus, widening the tibiofibular joint.

How Good Is the Test? To date, no studies have examined the validity of the external rotation test.

Special Tips for Improving Accuracy. The examiner may be able to feel the talus displace from the medial malleolus, which may indicate disruption of the deltoid ligament.

Thompson Test

There is controversy over who first described this test; regardless, the test was described in the 1950s to assess the integrity of the heel cord.

Description of the Maneuver. The patient is positioned prone on a table with his or her foot extended to the edge of the table. The clinician squeezes the calf muscle just distal to the place of widest girth and examines the movement at the foot. Negative squeeze test is indicated when plantar movement of the foot occurs.

Positive Findings. Positive test occurs when the calf is squeezed and no plantar movement occurs at the foot, which indicates a heel cord rupture.

How Good Is the Test? The Thompson test has been shown to have high sensitivity and specificity for evaluating heel cord rupture.

Squeeze Test

This test not only examines the integrity of the distal tibiofibular joint but also can assess for fractures of the tibia and fibula.

Description of the Maneuver. With the patient sitting supine with his or her foot on the table, the clinician grasps the midcalf and squeezes the tibia and fibula together. The clinician continues applying the same amount of pressure while moving distally toward the ankle.

Positive Findings. Pain in the lower leg may be indicative of a fracture or syndesmosis sprain.

Squeeze test

Source: University of California, San Francisco, Sports Medicine.

How Good Is the Test? To date, no studies have examined the validity of this test.

Bump Test

The bump test assists in the identification of fractures in the lower leg, talus, and calcaneus.

Description of the Maneuver. The patient should be seated with his or her injured leg hanging off the table. The examiner extends the knee with one hand and, using the palm of the other hand, bumps the calcaneus with increasing force until pain is elicited.

Bump test

Source: University of California, San Francisco, Sports Medicine.

Positive Findings. A positive test occurs when pain emanates from a fracture of the calcaneus, talus, fibula, or tibia.

How Good Is the Test? To date, no studies have examined the validity of this test.

Peroneal Tendon Subluxation Test

The peroneal tendon subluxation test is used to assess the integrity of the inferior peroneal retinaculum.

Description of the Maneuver. With the patient seated, the clinician instructs the patient to actively dorsiflex and evert the foot, while gently palpating over the peroneal tubercle. This test can also be performed passively.

Positive Findings. Positive findings occur when subluxation of the peroneal tendon over the tubercle is either visualized or palpated.

How Good Is the Test? To date, no studies have examined the validity of this test.

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See also Ankle Injuries; Foot Injuries; Musculoskeletal Tests, Foot

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Musculoskeletal Tests, Elbow

These musculoskeletal tests are used to diagnose common injuries around the elbow. The most common problems around the elbow include atraumatic, repetitive, overuse injuries such as lateral epicondylosis, medial epicondylosis, or ulnar neuropathy, usually caused by traction, friction, or compression of the nerve. Traumatic injuries usually involve a fall on the outstretched hand and include fractures and dislocations or the elbow. The radial head fracture is the most common. The elbow typically dislocates posteriorly. Finally, the disorder known as thrower's elbow presents a specific complex of injuries, including ulnar collateral ligament (UCL) sprains and damage to the joint surfaces. Following a trauma, it is not uncommon for people to develop a flexion contracture of the elbow, as loss of terminal extension is the most common complication following an elbow injury.

Examination of the Elbow

Observation

The examination of the elbow begins by first examining the elbow for skin changes such as bruising or discoloration as well as swelling. Swelling in the elbow joint itself, referred to as *effusion,* is checked by examining the back of the elbow for absence of the dimples of the joint. Soft tissue swelling directly at the tip of the elbow can be consistent with olecranon bursitis. Localized swelling near the medial or lateral epicondyles may suggest local tendon injury or ligament injuries, for example, to the ulnar collateral ligament.

One should also observe for normal bony and soft tissue contours anteriorly and posteriorly. In traumatic injuries, the elbow should be checked for bony deformity. The carrying angle of the elbow is the angle formed by the long axis of the humerus and ulna when the elbow is straight and the forearm is fully supinated. The normal carrying angle in males is 5° to 10°, while in females it is greater, approximately 10° to 15°. If the angle is less than this, the elbow is said to be in *cubitus varus,* and if the angle is greater than this, the position is referred to as *cubitus valgus*.

Atrophy of muscles around the elbow and more distally in the forearm should be noted. Chronic ulnar nerve problems may weaken and atrophy the ulnarly innervated muscles of the hand, which are located in the palm and dorsum of the hand.

Palpation

The examiner can palpate the bony landmarks of the elbow, in particular the lateral and medial epicondyles and the olecranon. These should make an isosceles triangle. When the arm is extended, these three points normally form a straight line across the elbow. This can be lost due to trauma, deformity, or arthritic conditions. Another bony landmark is the radial head, which can be felt over the lateral or outside portion of the elbow. Palpation of the radial head can be confirmed by feeling the rotation at the head when rotating the forearm in supination and pronation.

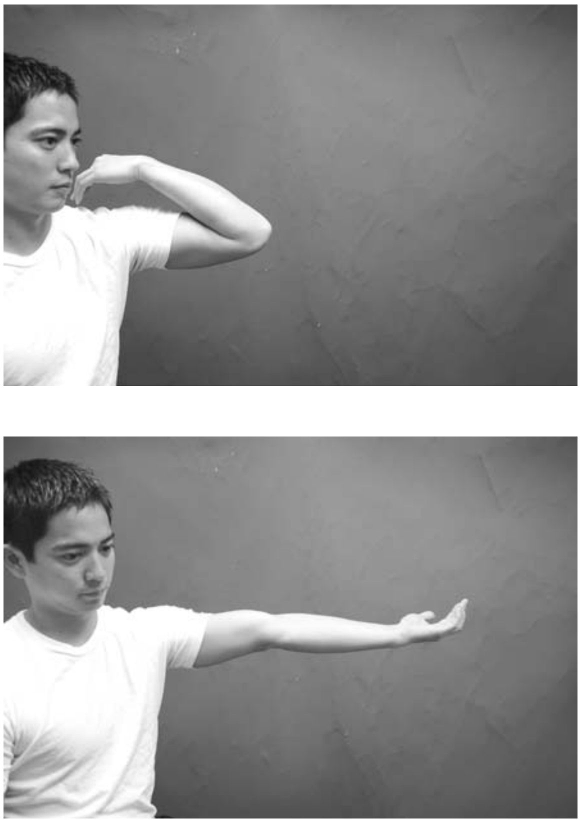
The ulnar nerve feels similar to a ropelike structure behind the medial epicondyle. It passes behind the medial epicondyle, within the cubital tunnel. It may subluxate over the medial epicondyle with flexion and extension of the elbow. Patients can develop *ulnar neuropathy* (numbness, tingling, and/or weakness), which most commonly affects the ulnar-most digits (ring and small fingers) as a consequence of elbow deformity or trauma.

One should palpate the antecubital fossa, including the flexor-pronator mass and the brachioradialis muscles, which form the distal contour of the antecubital fossa. Proximally, the contour is formed by the biceps. One should palpate the distal biceps tendon within the antecubital fossa as it inserts into the proximal radius. Loss of this structure indicates rupture to the distal biceps tendon. The brachial artery can be felt within the antecubital fossa as well.

The examiner can palpate the olecranon fossa along the superior aspect of the olecranon. This is a common location for osteophyte formation in posttraumatic arthropathy as well as for loose bodies that can affect terminal extension. Also, the medial and lateral gutters of the olecranon as it articulates with the humerus can be palpated for osteophyte formation and/or loose bodies. Synovial inflammation can also occur in this region and will present as bogginess and warmth.

Range of Motion

The examiner should observe the total *range of motion* of the elbow with regard to flexion, extension, pronation, and supination. The examination can be performed with the patient sitting, standing, or supine. The examiner should also examine the opposite side for comparison. Normal range of motion of the elbow is from 0° to 145° ± 10°, while the functional range of motion (motion required for normal daily activities) is from 30° to 130°. It is common for some individuals to hyperextend at the elbow up to 10°. Supination and pronation of the elbow should be checked. They are usually in the range of 85° ± 5° in each direction. Placing a pen or pencil in the hand can help estimate the amount of pronation and supination bilaterally. At least



Elbow flexion

Source: University of California, San Francisco, Sports Medicine.

50° of supination and pronation is required to perform the tasks of daily living.

Special Tests

Muscle/Tendon Tests

The lateral and medial tendons are the most common atraumatic elbow problems. These represent a majority of the elbow problems that will present, especially when there is no clear mechanism of injury.

Resisted Third-Digit Extension for Lateral Epicondylosis

This resisted strength test is performed to evaluate for lateral epicondylosis, or what is commonly labeled as tennis elbow. Lateral epicondylitis, or more appropriately lateral epicondylosis, mainly affects the extensor carpi radialis brevis tendon, with degenerative changes developing within the tendon origin just distal to the lateral epicondyle.

Description of the Maneuver. The maneuver is performed by extending the elbow fully, pronating the forearm, and then extending the wrist. The patient is then asked to fully extend all of the digits. The patient is then asked to keep his or her fingers extended against resistance, particularly the third or middle finger.

Positive Findings. A positive test will reproduce pain in the area of the lateral epicondyle.

How Good Is the Test? The test is reliable for evaluating for lateral epicondylosis, with a high sensitivity and moderate specificity.

Special Tips for Improving Accuracy. The examiner should focus on keeping the elbow fully extended, forearm fully pronated, and digits fully extended. Flexion at the elbow will reduce tension within the extensor carpi radialis brevis and reduce the accuracy of the test. The examiner should be aware of other potential causes of pain along the lateral epicondyle, such as radial tunnel syndrome, that could potentially be confused with lateral epicondylitis.

Resisted Wrist Extension for Lateral Epicondylosis

This test is classically performed for lateral epicondylosis, or what is commonly labeled as tennis elbow. Lateral epicondylitis, or more appropriately lateral epicondylosis, mainly affects the

Resisted third-digit extension for lateral epicondylosis

Source: University of California, San Francisco, Sports Medicine.

Resisted wrist extension for lateral epicondylosis

Source: University of California, San Francisco, Sports Medicine.

extensor carpi radialis brevis tendon, with degenerative changes developing within the tendon origin just distal to the lateral epicondyle.

Description of the Maneuver. The test is performed by asking the athlete to extend the wrist against resistance, with the elbow fully extended and the forearm maximally pronated.

Positive Findings. A positive test is reproduction of pain at the lateral epicondyle.

How Good Is the Test? The test is not as reliable as resisted digital extension because resisted wrist extension recruits other extensors, such as the extensor digitorum and extensor carpi radialis longus. It has a high sensitivity but reduced accuracy compared with resisted digital extension.

Resisted Wrist Flexion for Medial Epicondylosis

This test is employed to evaluate for medial epicondylosis or tendinopathy within the flexor-pronator mass. This condition is commonly called golfer's elbow. This is a degenerative tendinopathy rather than an inflammatory condition, making *epicondylosis* a more appropriate terminology than *epicondylitis*.

Resisted wrist flexion for medial epicondylosis

Source: University of California, San Francisco, Sports Medicine.

Description of the Maneuver. The maneuver is performed by having the patient extend and supinate the forearm. Next, the patient is asked to flex the wrist against resistance.

Positive Findings. Resisted flexion will elicit pain along the medial epicondyle and more specifically within the flexor pronator mass.

How Good Is the Test? The test has a high sensitivity and reproducibility.

Special Tips for Improving Accuracy. One should be aware of other potential causes of medial-sided elbow pain, such as ulnar collateral ligament disorders or ulnar neuropathy, which could also elicit pain with this condition. The examiner should fully examine the medial aspect of the elbow, in particular the medial collateral ligament and the ulnar nerve, to evaluate for any potential confounding conditions.

Resisted Pronation for Medial Epicondylosis

This test is employed to evaluate for medial epicondylitis or tendinopathy ("golfer's elbow") within the flexor-pronator mass, most commonly within the pronator teres.

Description of the Maneuver. The maneuver is performed by having the patient extend and supinate the forearm. Next, the patient is asked to pronate the wrist and forearm against resistance or turn the hand palm down.

Positive Findings. Resisted pronation testing will elicit pain along the medial epicondyle and more specifically within the flexor-pronator mass.

How Good Is the Test? The test has a high sensitivity and reproducibility.

Special Tips for Improving Accuracy. One should be aware of other potential causes of medial-sided elbow pain, such as ulnar collateral ligament disorders or ulnar neuropathy, which could also elicit pain with this condition. The examiner should fully examine the medial aspect of the elbow, in particular the medial collateral ligament and the ulnar nerve, to evaluate for any potential confounding conditions.

Distal Biceps Tendon Assessment

The examiner can assess for pain along the distal biceps tendon, which inserts into the proximal radius. Tendon injury is often tender on direct palpation of the tendon insertion. Resisted supination can reproduce the athlete's symptoms. Similarly resisted elbow flexion can be painful, though the biceps' primary role is as a supinator for the forearm.

Ligament Stress Tests

The ulnar collateral ligament is the most important stabilizer for the medial elbow and is the primary stabilizer for valgus stress. During overhead sports such as baseball pitching, a large valgus force is applied to the elbow, which makes the ligament vulnerable to overload. Also, a fall on an outstretched arm with a resultant valgus force with rotation can lead to injury of the ligament and sometimes even dislocation of the elbow. The lateral ligament complex of the elbow is more commonly injured in elbow trauma, particularly elbow dislocations. Injury to this structure can lead to varus instability of the elbow, as it is the primary stabilizer to varus stress at the elbow. In children under 6 years of age, the annular ligament may be naturally loose, leading to dislocation of the radial head when the arm is axially pulled, resulting in "nursemaid's elbow."

Valgus stress test

Source: University of California, San Francisco, Sports Medicine.

Valgus Stress Test

The elbow valgus stress test is commonly employed to evaluate for ulnar collateral ligament injury. Injuries to the ulnar collateral ligament are typically seen in throwing and overhead athletes when a valgus stress is applied acutely or in a repetitive fashion during sports.

Description of the Maneuver. The humerus should be maximally externally rotated; the forearm should be in maximal supination, with the patient's wrist and hand fixed; and a valgus stress should be applied toward the inside portion of the elbow, with the patient's arm flexed at 30°.

Positive Findings. Positive findings will elicit pain and opening of the ulno-humeral articulation with valgus stress.

How Good Is the Test? The test has a moderate sensitivity (not as sensitive as the milking maneuver) and high specificity.

Special Tips for Improving Accuracy. The examiner should keep the arm at 30° when evaluating the ligament, as this contributes the most to valgus stability. At higher degrees of flexion, the conformity of the elbow joint (ulno-humeral articulation) provides stability in addition to the ligament, making it less accurate. Also, concomitant conditions of the ulnar nerve can reduce the specificity of this condition as the test also places traction on the ulnar nerve and falsely creates a positive finding.

Milking Maneuver

This test was originally described as a more sensitive and specific test for ulnar collateral ligament conditions. The test evaluates for injury to the ulnar collateral ligament. It simulates a position for the elbow similar to throwing.

Description of the Maneuver. The "milking maneuver" is performed with the arm at 70°, with the valgus force applied by supporting the elbow and tractioning the thumb, similar to milking a cow.

Positive Findings. Positive findings will be elicited by pain along the ulnar collateral ligament.

How Good Is the Test? The test is more specific and accurate than the valgus stress test.

Special Tips for Improving Accuracy. The examiner should keep the arm positioned at 70° of flexion and apply a constant traction force on the abducted thumb.

Moving Valgus Stress Test

The moving valgus stress test evaluates for injury or laxity of the ulnar collateral ligament. The movement and stress on the elbow simulate positions for the elbow similar to throwing.

Description of the Maneuver. With the patient sitting with the shoulder abducted to 90°, the examiner applies a valgus force to the elbow until the shoulder is fully externally rotated. While maintaining the valgus torque, the examiner quickly extends the elbow to approximately 30°.

Positive Findings. A positive test reproduces pain at the ulnar collateral ligament, typically occurring maximally between 70° and 120° of flexion.

How Good Is the Test? The test has been described to be extremely sensitive in diagnosing conditions of the ulnar collateral ligament and has a high specificity as well.

Special Tips for Improving Accuracy. One must maintain a constant valgus torque to the fully flexed elbow by placing traction on the thumb while extending the elbow quickly.

Pivot Shift Test for the Elbow

This test is designed to evaluate for ligamentous injury to the lateral collateral complex of the elbow. The pivot shift test evaluates for injury to the lateral ulnar collateral ligament.

Description of the Maneuver. With the athlete lying supine with the arm overhead, the elbow is supinated, and valgus and axial forces are applied to it. The athlete may complain of pain or apprehension. Starting in extension, the elbow is flexed, with a reduction "clunk" occurring typically at 40° to 70° of flexion. Starting in flexion, the elbow can be subluxated with a constant valgus force as the arm is gradually brought into extension.

Positive Findings. A positive test indicates apprehension or instability as the arm is brought into extension with a constant valgus force.

Pivot shift test for the elbow

Source: University of California, San Francisco, Sports Medicine.

How Good Is the Test? The test has a high sensitivity and specificity in the willing patient.

Special Tips for Improving Accuracy. This test is difficult to conduct reliably in the patient who is awake. It is more reliably performed with the patient under anesthesia.

Neurovascular Tests

The ulnar nerve is often referred to as "the funny bone."

Tinel Sign or Tinel Test (Ulnar Nerve)

The Tinel sign can be used to evaluate for any number of compressive neuropathies, most commonly the median nerve at the wrist but also for the ulnar nerve at the elbow.

The ulnar nerve passes behind the medial epicondyle and courses into the forearm.

Description of the Maneuver. The test is performed by percussing with the index and middle fingers on the ulnar nerve along the posteromedial aspect of the elbow as it passes behind the medial epicondyle and courses into the forearm.

Positive Findings. A positive finding is elicited by pain and paresthesias that extend distally along the course of the ulnar nerve into the forearm.

Tinel test

Source: University of California, San Francisco, Sports Medicine.

How Good Is the Test? The Tinel sign has a moderate sensitivity and specificity for ulnar neuropathy.

Special Tips for Improving Accuracy. The examiner can evaluate the patient for subtle signs of neuropathy, including sensory testing with two-point discrimination, which has a higher sensitivity in detecting neuropathy than the Tinel test alone.

Ulnar Nerve Subluxation Test

The test evaluates for mobility and subluxation of the ulnar nerve when the elbow is brought from flexion into extension.

Description of the Maneuver. The elbow is passively moved from flexion into extension by the examiner. The examiner can place his or her fingers behind the medial epicondyle of the elbow.

Positive Findings. Subluxation of the ulnar nerve over the medial epicondyle is a positive finding as the elbow is brought into extension.

How Good Is the Test? The test is highly sensitive in detecting subluxation of the nerve but does not necessarily indicate that the patient has neuropathy.

Elbow Flexion Test

This test evaluates for ulnar nerve entrapment at the cubital tunnel, which is located along the posteromedial aspect of the elbow behind the medial epicondyle. Possible entrapment of the nerve at the cubital tunnel syndrome can be caused by various etiologies such as rheumatoid arthritis or posttraumatic arthritis.

Description of the Maneuver. The elbow flexion test is performed by having the patient fully flex the elbow with extension of the wrist and hold this position for 3 to 5 minutes.

Positive Findings. A positive finding is indicated by tingling and paresthesias along the ulnar nerve distribution.

How Good Is the Test? The test is sensitive and reliable in diagnosing ulnar nerve entrapment.

Special Tips for Improving Accuracy. The examiner must make sure that the patient holds this position for the specified time.

Median Nerve Compression at Pronator Teres

The median nerve can be compressed as it passes between the two heads of the pronator teres as it enters the forearm. This condition is referred to as *pronator syndrome*.

Description of the Maneuver. The test is performed by flexing the elbow to 90° and having the examiner strongly resist pronation as the elbow is gradually extended.

Positive Findings. A positive finding will be elicited by paresthesias along the median nerve distribution.

How Good Is the Test? The test has a high sensitivity with good reproducibility.

Special Tips for Improving Accuracy. Local tenderness in this condition can be observed over the medial nerve approximately 4 to 5 centimeters (cm) from the elbow distally. Resisted pronation with the elbow in the flexed position tests for pronator quadratus syndrome. It is important to evaluate for pronator teres syndrome by having the patient extend the elbow.

Allen test

Source: University of California, San Francisco, Sports Medicine.

Allen Test

This test evaluates for circulatory competence from the radial and ulnar arteries into the hand.

Description of the Maneuver. The Allen test is performed by having the patient open and close the hand several times as rapidly as possible and then squeezing the hand tightly. The examiner's thumb and index finger are then placed on the radial and ulnar arteries, respectively, compressing them. The patient then opens the hand while pressure is kept on the radial and ulnar arteries. Each artery is then sequentially tested by releasing pressure over the artery to see if the hand perfuses. Both hands should be tested for comparison.

Positive Findings. A positive finding is indicated if the hand fails to perfuse from either artery or if the circulation is sluggish from either the radial or the ulnar artery. It is also used to determine vascular dominance to the hand.

How Good Is the Test? The test has a good sensitivity and accuracy in diagnosing vascular disorders of the hand and forearm.

Special Tips for Improving Accuracy. The examiner should make sure to hold pressure over both arteries equally and that the patient rapidly opens and closes the hand at the beginning of the examination.

Check the Shoulder and the Neck

The examiner should consider problems at the shoulder and the neck, since they sometimes affect the elbow. Quick screening tests for shoulder problems include the Neer impingement test, where the shoulder is forward flexed maximally. If the test is positive, pain will be elicited at terminal forward flexion. A second test, referred to as the *Hawkins impingement test* (or sometimes only as the Hawkins test), can also be performed. The shoulder is abducted in the scapular plane to 90° and then internally rotated. If the test is positive, pain is elicited when the arm is internally rotated.

To screen for neck problems, the examiner can evaluate for the athlete's neck range of motion, including forward flexion, extension, rotation, and lateral bending. The Spurling sign is performed by turning and extending the head toward the ipsilateral arm with any symptoms and then applying an axial stress with the examiner's hand on top of the forehead. A positive test will elicit pain in the neck.

Sudheer C. Reddy and Anthony Luke

See also Elbow, Osteochondritis Dissecans of the; Elbow and Forearm Injuries; Elbow Bursitis; Medial Epicondyle Avulsion Fractures of the Elbow; Posterior Impingement Syndrome; Tennis Elbow; Ulnar Neuropathy

Further Readings

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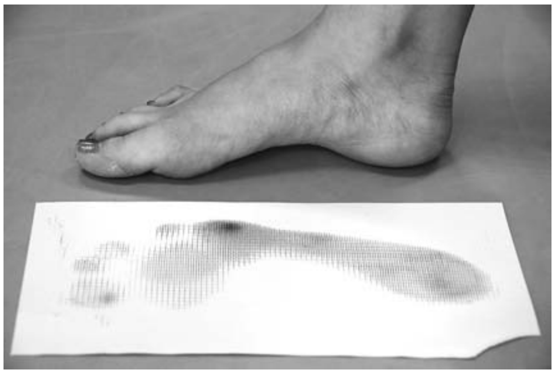
Musculoskeletal Tests, Foot

The foot provides the body's base of support, as it is the part of the body that comes into physical contact with the ground during gait. It provides stability to stand and move upright, acts in shock absorption, adapts to uneven surfaces or terrain, and acts as a lever for propulsion to enable the body to move in all directions. The foot is composed of 26 bones, which create 33 different joints. Due to the many bones and joints and the different roles the foot plays in locomotion, it is prone to injury, especially in activities or sports that require a significant amount of running or jumping. Walking forces increase to 1.2 times the body weight and can increase to twice the body weight while running. Jumping substantially increases the forces on the foot and lower extremities further to around five times the body weight. Therefore, it is not surprising that the foot often has problems with pressure points causing calluses or irregular deformities such as bunions. With repetitive stress, stress fractures can occur in several areas of the foot. Ligament sprains, acute fractures, and tendon and soft tissue problems can all occur. The foot is indeed a puzzle of bones, working together to produce complex movements that allow ambulation and make running, jumping, and other sports maneuvers possible.

In the foot itself, typically the location where the person feels the pain is the location of the problems. However, it is important when evaluating individuals with other joint problems to also examine their feet. Many problems occurring further up the kinetic chain can be attributed in some part to imbalances at the feet. When patients have biomechanical imbalances occurring at their feet, the body compensates in other joints of the body to maintain balance and function, which in turn can result in undue stress on the other joints. For individuals with foot problems, the clinician needs to establish when the patient has the pain. Morning pain at the heel when a person first gets out of bed is suggestive of plantar fasciitis. Does the pain increase with activities such as walking, exercising, and standing? What is the patient's occupation? Did the foot swell or bruise following the injury? Have the symptoms improved, worsened, or remained the same? What type of footwear does the patient wear to work, to workout, or during leisure activities, and has he or she recently changed the type of footwear that he or she normally wears? It is important to thoroughly evaluate the type of footwear that patients wear to ensure that they have the correct type for their foot posture. The average person takes between 3,000 and 5,000 steps per day; however, many people advocate 10,000 steps of activity per day for health. With those numbers expected, if the patient is wearing the wrong type of footwear, those steps can cumulatively add up to cause significant foot dysfunction.

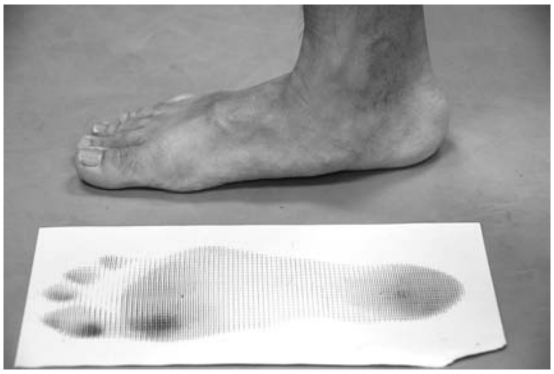
Examination of the Foot

Assessment of the foot begins when the patient first enters the room. The clinician should take note of the patient's gait pattern, his or her standing



Pes planus

Source: University of California, San Francisco, Sports Medicine.



Pes cavus

Source: University of California, San Francisco, Sports Medicine.

posture, the type of shoes the patient is wearing, and the wear on the soles of the shoes. The clinician should then evaluate the patient's standing posture with his or her shoes and socks removed.

Posture and Alignment

With the patient standing in a naturally comfortable position, the clinician can examine from the front and note the height of the arches (*pes cavus*—high arch; *pes planus*—flat feet). Functionally, one can observe the dynamic motion at the arch by asking the patient to go up on his or her toes and then return back to the standing position, to look for any collapse at the arch. From the posterior view, the clinician evaluates the position of the calcaneus and hindfoot region relative to the lower leg during weight bearing to determine the presence of hindfoot *varus* (heel deviated inward) or *valgus* (heel directed outward). Further evaluation of the feet out can be made by looking to see how many toes can be observed pointing inward or outward from the posterior view that relates to *in-toeing* ("pigeon toed") or *out-toeing*, respectively. It is normal to see two or three of the lateral toes from behind when the patient is standing relaxed. From a lateral perspective, the clinician should evaluate the alignment of the toes and nail deformities. The toes are examined for flexion abnormalities at the joints, referred to as *claw toe*, *hammertoe*, or *mallet toe* deformities. Excessive valgus positioning of the first metacarpal phalangeal joint more than 20° results in the development

Anterior foot view

Source: University of California, San Francisco, Sports Medicine.

of a “bunion” (*hallux valgus*). Similarly, a bunionette can develop on the fifth metatarsal head, with the fifth toe pointing inward. During the postural assessment, any differences observed bilaterally as well as any signs of injury should be noted: inflammation, redness, or discoloration. A detailed evaluation of the other joints of the patient’s lower extremity is important to ensure a thorough assessment of his or her posture.

Footwear

For all lower extremity injuries, it is important to examine the footwear of patients, not only for clues of foot dysfunction but also because the type of footwear can play a major role in the development of foot pathologies. Normal wear to the shoes should be seen below the ball of the foot, lateral side, and the posterolateral corner of the heel. Old shoes can break down and lose their support for the feet. Wearing of the sole decreases its shock absorption properties. Patients who often wear high-heeled or platform shoes are at increased risk of developing foot pathologies. Individuals who wear high-heeled shoes continuously may also be prone to developing knee injuries and back pain, because to maintain an upright posture, there is an increase in the (lordotic) curve of the lumbar spine. A narrow toe box in the shoe can lead to additional foot pathologies such as bunions, foot fractures, interdigital neuromas, and mechanical foot pain (*metatarsalgia*) for an individual with a wide ball of the foot.

Lateral foot view

Source: University of California, San Francisco, Sports Medicine.

Medial foot view

Source: University of California, San Francisco, Sports Medicine.

Posterior foot view

Source: University of California, San Francisco, Sports Medicine.

Palpation

With 26 bones constituting the foot, there are many structures in which injuries can occur. During the examination, it is important to thoroughly palpate the bony and soft tissue structures, starting with the hindfoot and moving on the midfoot and forefoot. The hindfoot consists of the talus, calcaneus, and Achilles tendon. Palpate along the Achilles tendon as it inserts onto the calcaneus. Note any tenderness along the tendon and insertion site. During puberty, adolescents may develop calcaneal pain due to the development of a *traction apophysis*; this is known as Sever disease. The insertion of the Achilles tendon is over a growth plate in the calcaneus, and excessive activity can lead to irritation of the calcaneus. Symptoms usually include pain with activity and palpation and usually diminish once the individual has reached maturity.

Palpate the lateral aspect of the foot that includes the lateral malleolus, calcaneus, and talus. Palpate over the anterior talofibular ligament and calcaneofibular ligaments. Feel along the entire course of the fibularis longus and brevis as they run posterior to the fibular and course around the lateral malleolus. Palpate the insertion of the fibularis brevis on the base of the fifth metatarsal. Ankle sprains can lead to several different structure injuries in the foot and ankle. Commonly, lateral ankle sprains cause injury to the lateral ligaments; however, they can also cause an avulsion fracture at the base of the fifth metatarsal due to the involvement of the fibularis brevis in counteracting the inversion moment. Other sites of possible injury include fracturing of the lateral malleolus or injury to the distal tibiofibular syndesmosis, but these usually involve some type of rotary moment.

On the anterior aspect of the foot, palpate bony structures that include the distal tibia, talus, navicular cuneiforms, cuboid, metatarsals, and phalanges, in addition to palpating the joint spaces between each. Stress fractures to the tarsal and metatarsal bones are common among runners and other highly active individuals. *Stress fractures* are caused by repetitive microtrauma to the structure of the bone, most commonly seen in running sports, dancing, and high-impact activities. Individuals with a stress fracture will have localized point tenderness on the bone and often have an area of soft tissue swelling immediately surrounding the painful spot.

On the medial aspect of the foot, palpate along the medial malleolus and calcaneus, over the navicular tubercle, and along the metatarsals. Palpate the first metatarsalphalangeal joint, as individuals with hallux valgus can develop a bunion over this area that may be tender, especially medially. Soft tissue structures to feel include the deltoid ligament and spring ligament, which are located between the navicular tubercle and the sustenaculum tali.

The plantar aspect of the foot can be palpated at the calcaneus and at the medial portion of the heel, where the calcaneal tubercle is located. This insertion site for the plantar fascia can be tender in individuals with *plantar fasciitis*. In long-standing cases, a bone spur can develop in this area. Other bony structures to feel are the metatarsal heads, especially the first metatarsal head because two sesamoid bones are located here and are prone to fracture. Soft tissue palpation should include the plantar fascia along its length, which is more pronounced when the foot is dorsiflexed. Tenderness between the metatarsals distally between the heads can be indicative of an *interdigital neuroma,* which most commonly occurs between the third and fourth toes. In some cases of neuroma, a small, tender soft tissue nodule may be palpable. Assess the fat pads of the foot that are located over the base of the calcaneus and the metatarsal heads. Also, note any callus development in the sole of the foot, which can indicate poor footwear selection.

Range of Motion

The first movement to assess at the foot is active range of motion. With patients seated with their foot hangingoff the table, they can actively perform plantarflexion, dorsiflexion, supination, and pronation of the foot, as well as toe extension, flexion, abduction, and adduction. For normal gait to occur, individuals must have at least 20° of plantarflexion and 10° of dorsiflexion. *Supination* is the combination of inversion, adduction, and plantarflexion of the foot, while *pronation* involves eversion, abduction, and dorsiflexion of the foot. If no inversion occurs, the foot is considered to be unstable or there is weakness of the tibialis posterior.

Passive range of motion of the joints is also important to examine the soft tissue and if there is any joint arthritis present. Bilateral comparison of the passive movements is important. The clinician should examine any limitations in dorsiflexion, plantarflexion, supination, and pronation seen on active motion. In addition, gliding of the midfoot and forefoot joints should be performed to examine adequate movement of each. Restricted movements at one joint tend to cause increased movement and undue stress to the surrounding joints.

The toes should be examined as well. Painful hyperextension of the first metatarsal phalangeal joint is known as *turf toe,* essentially a sprain of the joint ligaments. It can be a debilitating injury and is commonly caused when the hallux is placed under excessive loads. Shoes with a flexible forefoot or activities played on artificial turf are common causes of turf toe. Limited motion at the big toe can be suggestive of osteoarthritis of the first metatarsal phalangeal joint, known as *hallux rigidus*.

Palpation of the dorsal pedal pulse

Source: University of California, San Francisco, Sports Medicine.

Palpation of the tibialis posterior pulse

Source: University of California, San Francisco, Sports Medicine.

Resistive range of motion should be performed to examine the contractile tissues of the foot and lower extremity. With the patient in a seated position, the clinician should perform an isometric strength test for dorsiflexion, plantarflexion, supination, pronation, toe extension, and toe flexion. These tests should be performed *bilaterally,* and the strength results depend on the individual's age and sex.

Neurovascular Exam

Evaluation of the neurovascular systems of the lower extremity is an important step to complete a thorough examination. To evaluate circulation in the foot, the dorsal pedal pulse can be palpated over the dorsal aspect of the foot, and the posterior tibial artery is best felt immediately posterior to the medial malleolus. The capillary refill of the toes is checked by pressing firmly for 5 seconds over the tip of one of the toes and then releasing the pressure, which causes the skin to blanch and then return back to its normal color. Normal capillary refill occurs in 2 to 3 seconds.

Testing of the peripheral nerves in the lower extremity should not be overlooked because pathologies higher up in the lower extremity of the spinal column can result in muscle weakness and atrophy and sensory deficits. The lower extremity screen should include manual muscle testing, deep tendon reflexes, and sensory testing. *Manual muscle testing* should include the hip flexors, quadriceps, anterior tibialis, extensor hallucis longus, and gastrocnemius. *Deep tendon reflexes* include the patellar tendon and Achilles tendon. *Sensory testing* involves seven different nerve root dermatomes: L1 is located over the anterior hip and lateral gluteal region, L2 over the anterior and lateral thigh, L3 over the distal thigh, L4 over the medial aspect of the lower leg and foot, L5 over the anterior aspect of the lower leg and foot, S1 over the lateral aspect of the lower leg and foot, and S2 over the calf and bottom of the foot. The neurological exam should be equal bilaterally, and any differences may suggest trauma to the peripheral or spinal nerve roots.

Special Tests

Navicular Drop Test

The test is used to assess the arch shape of the foot and quantify midfoot mobility.

Description of the Maneuver. With the patient weight bearing, the foot is placed in a neutral talus position. To find the neutral talus position, the clinician palpates the medial and lateral aspects of the talus with his or her thumb and forefinger. The patient is then asked to rotate his or her trunk to the right and left. The neutral talus position is found when the clinician cannot feel the head of the talus bulge on either side. To perform the navicular drop, the clinician positions the foot in a neutral talus position, then measures the height of the navicular turbercle using a ruler. Then the patient is asked to relax in his or her standing position, and the measurement is taken again. The difference in the two numbers indicates the amount of foot pronation or flattening of the medial longitudinal arch.

Positive Findings. A difference greater than 10 millimeters (mm) is considered abnormal.

How Good Is the Test? To date, no studies have examined the validity of the navicular drop test.

Special Tips for Improving Accuracy. This test depends on the experience of the clinician and finding the neutral talus position.

Homans Sign

This test is used to diagnose the presence of a blood clot in the veins of the leg, known as *deep vein thrombophlebitis.*

Description of the Maneuver. With the patient seated, the clinician quickly dorsiflexes the foot with the knee extended and holds the ankle in dorsiflexion. The clinician can palpate the calf muscle.

Positive Findings. Pain when the foot is dorsiflexed and tenderness when the clinician palpates the calf are indicative of a positive finding.

How Good Is the Test? To date, no studies have examined the validity of the Homans sign.

Special Tips for Improving Accuracy. Other symptoms include swelling of the leg, a diminished or absent dorsal pedal pulse, and changes in skin pallor. An individual suspected of having a deep vein thrombosis should be immediately referred to the emergency room for further evaluation.

Homans sign

Source: University of California, San Francisco, Sports Medicine.

Anterior Drawer Test

The anterior drawer test is a test used to examine the integrity of the anterior talofibular ligament, which is frequently injured during an inversion ankle sprain.

Description of the Maneuver. The patient should be seated with his or her knee bent and ankle at 20°. The clinician stabilizes the distal tibia with one hand while grasping the heel with the other hand and applying an anterior force to the heel. This test should be performed bilaterally to compare for differences in anterior translation.

Positive Findings. Pain or increased joint laxity in the injured ankle indicates disruption of the anterior talofibular ligament. Visually, a dimple may be seen by the clinician while performing this test.

How Good Is the Test? The validity testing demonstrates that the anterior drawer test has high sensitivity, moderate specificity, high positive predictive value, and moderate negative predictive value.

Anterior drawer test

Source: University of California, San Francisco, Sports Medicine.

Talar tilt test

Source: University of California, San Francisco, Sports Medicine.

Talar Tilt Test

The talar tilt test is a ligamentous stress test that examines the integrity of the lateral ankle ligaments, primarily the calcaneofibular ligament.

Description of the Maneuver. With the patient seated, knee bent, and foot in neutral or slightly dorsiflexed position, the clinician stabilizes the distal tibia with one hand while applying an inversion force to the foot.

Positive Findings. Pain or increased joint laxity in the involved ankle. Pain may be over the calcaneofibular ligament or the anterior talofibular ligament, depending on the positioning of the ankle.

How Good Is the Test? To date, no studies have examined the validity of the talar tilt test.

External Rotation Stress Test or Kleiger Test

The test was first described by Barnard Kleiger and is used to identify syndesmotic injuries.

Description of the Maneuver. The patient is seated with his or her knee bent on an exam table. The clinician stabilizes the distal tibia while externally rotating the foot.

Positive Findings. Pain in the anterolateral ankle joint is felt, or there is an increased external rotation of the foot when compared bilaterally. External rotation of the talus applies pressure to the lateral malleolus, widening the tibiofibular joint.

How Good Is the Test? To date, no studies have examined the validity of the external rotation stress test.

External rotation stress test or Kleiger test

Source: University of California, San Francisco, Sports Medicine.

Special Tips for Improving Accuracy. The examiner may be able to feel the talus displace from the medial malleolus, which may indicate disruption of the deltoid ligament.

Thompson Test or Squeeze Test

There is controversy over who first described this test; regardless, the test was described in the 1950s to assess the integrity of the heel cord.

Description of the Maneuver. The patient is prone on a table with his or her foot extended off the edge of the table. The clinician squeezes the calf muscle just distal to the place of widest girth and examines the movement at the foot. Negative squeeze test occurs when plantar movement of the foot occurs.

Thompson test or squeeze test

Source: University of California, San Francisco, Sports Medicine.

Positive Findings. Positive test occurs when the calf is squeezed and no plantar movement occurs at the foot, which indicates a heel cord rupture.

How Good Is the Test? The squeeze test has been shown to have high sensitivity and specificity for evaluating heel cord rupture.

Ottawa Ankle Rules

The Ottawa Ankle Rules were developed to assist physicians in determining whether individuals with foot or ankle pain require X-rays to rule out the possibility of a fracture. Prior to the development of these rules, many individuals received unnecessary X-ray imaging. Testing of the Ottawa Ankle Rules have demonstrated high sensitivity in identifying individuals with foot and ankle fractures, which has resulted in significant reduction of unnecessary X-rays. According to the ankle rules, X-rays are required if there is

- any bony pain in the malleolar region,
- bone tenderness in the distal 6 centimeters (cm) of the posterior edge of the tibia or tip of the medial malleolus,
- bone tenderness in the distal 6 cm of the posterior edge of the fibula or tip of the lateral malleolus, and
- inability to walk immediately and four steps in the emergency department.

Additionally, X-rays are indicated for individuals with foot pain if there is

- any bony pain in the midfoot region,
- bone tenderness over the base of the fifth metatarsal,
- bone tenderness over the navicular bone, and
- inability to walk immediately and four steps in the emergency department.

Derek Hirai and Anthony Luke

See also Foot Fracture; Foot Injuries

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Musculoskeletal Tests, Hand and Wrist

The tests in this entry are used to diagnose common injuries in the hand and wrist. Injuries of the hand and wrist are some of the most common conditions observed by sports medicine physicians. The wrist and hand are particularly complex joints since the joints themselves are small and perform extremely fine, complicated movements. The most common problems of the hand and wrist include carpal instability, triangular fibrocartilage complex (TFCC) tears, de Quervain tenosynovitis, ulnar collateral ligament injury of the thumb (gamekeeper's thumb), arthritis of the CMC (carpometacarpal joint) of the thumb, and carpal tunnel syndrome. Fractures of the wrist, in particular the distal radius, are the most common type of fractures in the upper extremity and are caused by falls on an outstretched hand (commonly known as FOOSH).

Examination of the Hand and Wrist

Observation

The examination of the hand and wrist should commence with an observation of the digits and wrist for any evidence of masses or deformity as well as the patient's willingness to use the hand. Observe for symmetry between both hands and wrists with regard to color, atrophy, hair patterns, and position of the wrist and digits. Presence of the digital cascade should be noted (see the first image). Asymmetry can indicate evidence of pathology. Of note, the dominant hand tends to be slightly larger than the nondominant hand. Lack of use or avoidance of a particular portion of the hand with regard to grasping or holding objects can indicate pathology as well as neuromuscular dysfunction. Nodules or ganglions on the wrist and digits are common as well and should be noted if present. Bouchard and Heberden nodes are present on the proximal interphalangeal and distal interphalangeal joints, respectively, and are found in the setting of osteoarthritis of the interphalangeal joints. The examiner should also take note of the scars present as they may indicate prior surgery or trauma. Fingernails should also be inspected for color and shape. Various pathological conditions can affect the appearance of the fingernails, such as anemia, psoriasis, or vascular insufficiency.

Palpation

Palpation of the hand and wrist is an important aspect of the examination of the hand and wrist.

The digital cascade

Source: University of California, San Francisco, Sports Medicine.

One should take note of the skin temperature of both hands. As with visualization, asymmetry can indicate pathology. One should take note of the texture of both hands. Increased dryness of one hand could indicate neurologic dysfunction. Palpation of both the radial and ulnar pulses is important as well. Asymmetry could indicate vascular disorders such as thrombosis or aneurysm.

Palpation of the hand and wrist is important as there are a number of anatomical landmarks of which the clinician must be aware. Palpation of the *anatomical snuffbox* along the radial aspect of the wrist evaluates the scaphoid. The snuffbox is marked by the abductor pollicis longus and extensor pollicis brevis on the radial aspect and the extensor pollicis longus along the ulnar aspect of the snuffbox.

Palpation of another bony landmark is the *Lister tubercle*. This is a tubercle (bony prominence) present along the dorsal aspect of the wrist. It is an important landmark as this is where the extensor pollicis longus tendon courses as it passes along the dorsum of the wrist. Distal to this landmark is the lunate fossa of the distal radius, where the wrist can be aspirated if necessary. The lunate can also be palpated in this location. Pain on palpation can indicate pathology of the lunate, such as in *Kienbock disease* (osteonecrosis of the lunate). The ulnar snuffbox is the soft area just distal to the ulna. It contains the *triangular fibrocartilage complex,* which is a fibrocartilaginous disk that aids in load transmission across the radioulnar joint. Palpation of the ulnar styloid is important as well, along with the extensor carpi ulnaris that lies along the ulnar aspect of the wrist. Palpation of the metacarpals and carpometacarpal joints is important to evaluate for deformity that can indicate prior trauma. Boxer's fractures are common, as are fractures of the head-neck junction of the small finger metacarpal. Range of motion of the metacarpophalangeal and interphalangeal joints should be noted as well, and any asymmetry should be documented.

Scaphoid palpation in the anatomical snuffbox

Source: University of California, San Francisco, Sports Medicine.

Palpation of the triangular fibrocartilage complex (TFCC)

Source: University of California, San Francisco, Sports Medicine.

Range of Motion

Range of motion at the wrist is approximately 60° to 70° of wrist extension and 70° to 90° of wrist flexion. Radial deviation at the wrist is 15° to 20°, while ulnar deviation is around 35°. Range of motion at the metacarpophalangeal (MCP) joints includes 100° of flexion and 60° range of motion in the abduction-adduction plane. The proximal interphalangeal (PIP) joints have approximately 100° of flexion (range of motion from 0° to 100°), while the distal interphalangeal (DIP) joints have approximately 80° of flexion.

Special Tests: Muscle/Tendon Tests

Intrinsic Tightness Test for Contracture of the Lumbricals and Interossei Muscles of the Hand

This test is used to evaluate for contracture of the intrinsic muscles (interossei and lumbricals), which can occur in neurological conditions, most commonly with brachial plexus injuries or stroke.

Description of the Maneuver. The test is performed by positioning the MCP joints initially in extension and the PIP joints in extension. PIP flexion is then evaluated in this position. The MCP joints are then flexed, and the PIP joints are again held in an extended position. PIP flexion is again evaluated.

Positive Findings. A positive test result for intrinsic tightness is demonstrated when there is less PIP flexion with the MCP joints hyperextended than when they are flexed.

How Good Is the Test? This test is reliable for evaluating intrinsic tightness.

Special Tips for Improving Accuracy. Evaluate the MCP joints in extension first, and then bring them into flexion. Positioning the wrist in neutral position with regard to extension and flexion is also beneficial. This will remove any chance of the extrinsic flexors and extensors affecting motion at the MCP joints.

Elson Test

This test evaluates for a *boutonniere deformity*, which occurs when there is injury to the central slip of the extensor mechanism. The resulting deformity is a PIP flexion contracture and a compensatory DIP hyperextension.

Description of the Maneuver. The test is performed by bending the PIP joint 90° over the table. The examiner then places a finger on the middle phalanx. The patient is then asked to extend the digit against resistance.

Positive Findings. A positive test result is indicated by the DIP joint going into rigid extension due to all forces being distributed to the terminal tendon through intact lateral bands. A negative test result is demonstrated by the DIP joint remaining floppy.

Special Tips for Improving Accuracy. The patient should be in a seated position. Flex the injured digit over the edge of a table. This is the best way of isolating and testing the PIP joint.

Finklestein test

Source: University of California, San Francisco, Sports Medicine.

Finklestein Test

This is a test that evaluates for *de Quervain disease*, or *tenosynovitis*, which is an inflammation of the first dorsal compartment of the wrist. The first dorsal compartment of the wrist includes the abductor pollicis longus and extensor pollicis brevis tendons. It is most common in women 30 to 50 years old.

Description of the Maneuver. The test is performed by placing the patient's thumb within the patient's clenched fist. The wrist is then positioned in ulnar deviation, placing the first dorsal compartment under tension.

Positive Findings. A positive test result is indicated by pain along the involved compartment with this maneuver.

How Good Is the Test? This test is highly sensitive for evaluating de Quervain tensosynovitis.

Special Tips for Improving Accuracy. Place the patient's thumb within the palm of his or her hand, and then have the patient clench a fist.

Neurovascular Tests

Tinel Sign

The Tinel sign or Tinel test can be used to evaluate for any number of compressive neuropathies

Tinel sign

Source: University of California, San Francisco, Sports Medicine.

Dirkin compression test

Source: University of California, San Francisco, Sports Medicine.

but most commonly for the ulnar nerve about the elbow and the median nerve at the wrist.

Description of the Maneuver. The test evaluates for median neuropathy at the wrist by percussing along the median nerve as it courses under the flexor retinaculum at the wrist.

Positive Findings. A positive test result is indicated by numbness and tingling within the thumb, index finger, and middle digits.

How Good Is the Test? This test is moderately sensitive in diagnosing carpal tunnel syndrome.

Dirkin Compression Test

The Dirkin compression test can also be used to evaluate for carpal tunnel syndrome.

Description of the Maneuver. The test is performed by the examiner placing his or her thumb directly on the carpal tunnel and exerting compression on the median nerve within the carpal tunnel for a period of 1 minute.

Positive Findings. A positive test result is indicated by numbness and tingling within the thumb, index finger, and middle digits.

How Good Is the Test? This test has better sensitivity in diagnosing carpal tunnel syndrome than the Tinel sign—approximately 90% sensitivity.

Phalen Test

This test is also used to evaluate for carpal tunnel syndrome.

Description of the Maneuver. Position the patient's wrist in maximal flexion, and have him or her maintain this position for 1 minute.

Positive Findings. Pain and paresthesias can be felt along the median nerve distribution (thumb, index finger, and middle digits). It is often present when carpal tunnel syndrome is in the advanced stages.

Phalen test

Source: University of California, San Francisco, Sports Medicine.

How Good Is the Test? This test is not as sensitive as the Dirkin compression test as the test is often positive once the condition has become more advanced.

Special Tips for Improving Accuracy. Have the patient flex both wrists at the same time and hold in position for 1 minute. This will allow a comparison with the contralateral side.

Ligament Stress Tests

Watson Test for Carpal Instability

Carpal instability can affect the individual carpal articulations and also the midcarpal articulation. Dorsal intercalated instability refers to a disruption of the scapholunate ligament. The Watson test is the best method for evaluating for dorsal intercalated instability.

Description of the Maneuver. The best way of evaluating this is to place the examiner's thumb along the scaphoid tubercle and bring the wrist from ulnar deviation to radial deviation. This will cause a palpable click of the proximal aspect of the scaphoid over the dorsal rim of the distal radius.

Positive Findings. A palpable click will be elicited as the proximal aspect of the scaphoid goes over the dorsal rim of the distal radius as the wrist is brought from ulnar deviation into radial deviation. This can also be accompanied by pain.

How Good Is the Test? This test has moderate sensitivity and specificity in diagnosing scapholunate instability.

Special Tips for Improving Accuracy. Maintain constant pressure on the scaphoid tubercle as the wrist is brought into radial deviation. Place an index finger over the scaphoid dorsally to evaluate the position of the proximal aspect of the scaphoid.

Lunotriquetral Ballottement Test

This test is used to evaluate for sprains of the lunotriquetral ligament.

Description of the Maneuver. This test is performed by fixing the lunate in position with the thumb and index finger of one hand while using the thumb and index finger of the opposite hand to displace the triquetrum dorsally and then plantarly.

Positive Findings. Patients with injury to this ligament will complain of pain and instability.

How Good Is the Test? This test has moderate sensitivity and specificity in diagnosing injury to the lunotriquetral ligament.

Special Tips for Improving Accuracy. It is best for both the clinician and the patient to be seated for this examination. Have the patient flex the elbow as well for more optimal positioning of the wrist prior to evaluation.

Ulnocarpal Stress Test

This test is used to evaluate for injuries to the triangular fibrocartilage complex (TFCC).

Description of the Maneuver. This test is performed by positioning the wrist in maximal ulnar deviation while passively bringing the wrist from maximal pronation to supination.

Positive Findings. Patients with an injury to the TFCC will experience pain and clicking in the setting of a TFCC tear.

Special Tips for Improving Accuracy. One must compare both the injured and uninjured wrists as clicking can be present at baseline.

Ulnar Ligament of the Thumb MCP Joint

Stress tests of this ligament are used to evaluate for an injury to the ulnar collateral ligament of the thumb (gamekeeper's thumb).

Description of the Maneuver. This test is performed by first positioning the thumb MCP joint in 30° flexion and then applying a valgus load to the joint. The thumb must be held along the metacarpal shaft as well to prevent rotation at the MCP joint. The thumb MCP joint is then positioned in extension (0°), and the test is repeated.

Positive Findings. A positive test result with the MCP joint in 30° of flexion is indicated by greater

Ulnar collateral ligament stress test

Source: University of California, San Francisco, Sports Medicine.

than 30° of opening at the MCP joint with a valgus stress or greater than 15° compared with the contralateral side. If there is greater than 30° of opening or greater than 15° compared with the contralateral side with the thumb in extension, then there is injury to the accessory collateral ligament as well.

Special Tips for Improving Accuracy. This test is more accurately performed under fluoroscopy to properly estimate the degree of laxity.

Thumb CMC Grind Test

This test is used to evaluate for arthritis of the basal joint (carpal-metacarpal) articulation. Arthritis of the basal joint of the thumb results in attenuation of the volar beak ligament, which is the primary ligamentous stabilizer of the thumb CMC articulation.

Description of the Maneuver. The test is performed by stabilizing the trapezium with one hand and then forcefully dorsally attempting to subluxate the thumb metacarpal on the trapezium while simultaneously compressing the metacarpal against the trapezium.

Positive Findings. Patients with arthritis at the CMC joint have pain and instability with this test.

Special Tips for Improving Accuracy. One must differentiate this from arthritis within the wrist itself at the scaphoid-trapezial-trapezoid (STT) articulation. Palpation along this articulation and along the thumb CMC articulation can differentiate the two conditions.

Other Points to Consider in Examination of the Wrist and Hand

The examiner should be careful to also inspect the elbow for deformity and total range of motion. Injury to the elbow can be reflected in loss of the carrying angle or loss of range of motion that can affect the ability to position the hand and wrist in space. Evaluate the neck with regard to range of motion and pain with range of motion. Cervical radiculopathy can lead to numbness, tingling, and/or weakness within the hand and wrist. Evaluate for the Spurling sign, which is performed by tilting the neck to the ipsilateral shoulder and then applying an axial stress with the examiner's hand on top of the forehead. A positive test will elicit pain in the neck.

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See also Hand and Finger Injuries; Wrist Injuries

Further Readings

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Musculoskeletal Tests, Hip

Musculoskeletal tests are used to diagnose common injuries around the hip and the pelvis. During activities, the hips link the lower extremities to the central skeleton. Many people consider the pelvis a portion of the hip when they describe their pain, though it is also an extension of the lumbar spine. The hip joint provides significant contact between the ball and the socket, making it a very secure and stable joint. Whenever hip problems are suspected, it is prudent to always check the back and vice versa.

Many sports require extreme motion in the hip, for example, jumping in track-and-field events; kicking in dance, martial arts, and soccer; and performing tumbling maneuvers in gymnastics. Because there is a lot of motion around the hip, there are frequent muscle strains and tendon strains. External problems of the hip typically involve the tendons surrounding the hip, namely, the iliopsoas anteriorly, or the tensor fascia lata, which is joined to the iliotibial band laterally. These can snap over bony prominences and become painful from mechanical friction or eccentric load. Lateral hip pain often presents due to greater trochanteric bursitis or gluteal tendinopathy as the tendons insert into the greater trochanter. An important diagnosis not to miss is a stress fracture of the hip, which can affect athletes subjected to repetitive impact. These occur typically on the inferior aspect of the neck of the femur but can also occur on the shaft or the superior aspect of the neck. These fractures are dangerous and can lead to displacement.

In some individuals, the neck of the femur bumps against the rim of the socket (acetabulum) during the extreme range of motion that occurs with hip flexion and internal rotation. This can occur because the hip socket is shallow (hip dysplasia), allowing increased motion and less bony support for the joint, or because there is bony overgrowth, resulting in more bony impingement with movement. These problems are often referred to as femeroacetabular impingement. Degenerative changes in the cartilage surface of the joint or involving the cartilage rim or labrum can occur, causing internal derangements in the joint. Since much of the forces during sports and daily activity are transmitted from the leg to the spine through the hip, arthritis in the hip can occur in older athletes.

Examination of the Hip and Pelvis

Observation: Posture and Alignment

Lower Extremity Alignment. The examination of the hip includes assessment of posture and lower extremity alignment. The alignment at the knees can be quickly screened by asking the athlete to stand with the ankles together, observing the knees. If there is a wide space between the knees when the athlete stands with the feet together and the athlete appears to be "bowlegged," the athlete has *genu varum,* indicating that the lower leg angles medially after the knee. Similarly, if the athlete appears "knock-kneed" and has difficulty putting the feet together due to the proximity of the knees, it is called *genu valgus* alignment. With the feet together pointing forward, if the kneecaps point inward, it is called "squinting patellae" and often represents a rotational malalignment at the hips called *femoral anteversion,* where the hips are angled such that the knees and lower legs rotate inward. Femoral anteversion is one reason for in-toeing or "pigeon-toed" alignment.

Femoral Anteversion. Femoral anteversion is a common malalignment at the hip that can result in subtle rotational deformity in the lower extremities. The underlying cause is a forward angulation of the femoral neck in relation to the shaft and coronal plane of the pelvis. Normally, this angle is approximately 12° to 15°. An increased anterior angle results in more femoral anteversion, causing functional internal rotation at the knees during gait.

Gait. The athletes can be observed performing functional activities such as walking, hopping, squatting, walking on their heels, and walking on their toes to test the function of the knees and other joints in the lower extremities. A "lurching gait" typically suggests that the individual has a hip problem. As the patient walks, he or she bends laterally toward the affected side during weight bearing. Leaning toward the problem side helps decrease the forces of gravity directly on the head of the hip, resulting in less pain and stress on the hip. This is typical for someone with a history of arthritis in the hip or previous trauma.

Back Examination. For patients with chronic pelvic or hip pain, it is helpful to perform an appropriate back exam. During the assessment, look for *scoliosis* or anterior-posterior asymmetries in posture (e.g., head forward, shoulder forward, or increased curvature at the low back, known as *lordosis*).

Tests: Posture and Alignment

Trendelenburg Test

The Trendelenburg test examines for weakness or instability of the hip abductors, primarily the gluteus medius.

Description of the Maneuver. The patient balances first on one leg, raising the nonstanding knee toward the chest. The examiner can stand behind the athlete and observe for any misalignment and dropping of the pelvis or buttock on the nonstance side.

Positive Findings. If the pelvis on the side of the nonstance leg rises, the test is negative. If the pelvis on the side of the nonstance leg falls, the test is positive, indicating weakness or instability of the hip abductors, primarily the gluteus medius, on the stance side.

How Good Is the Test? The Trendelenburg test has moderate to good sensitivity and specificity for detecting a tear in the gluteus medius muscle.

Trendelenburg test (negative)

Source: University of California, San Francisco, Sports Medicine.

Functional Squat

The athlete can be asked to quickly squat, fully flexing at the hips, knees, and ankles. This can help quickly screen for any limitations in range of motion at any of these joints.

Leg Length Discrepancy

The leg length testing in the supine position can assess for both true and apparent leg length discrepancies. A true leg length discrepancy occurs when there is an actual difference in the femur and/or tibia between the two legs. An apparent leg length discrepancy occurs when one leg appears shorter than the other. However, there is no true difference in the length of the bones; rather, there is a functional or structural pelvic, spinal, or foot asymmetry.

Description of the Maneuver. With the patient lying supine, the examiner can assess for a true leg length difference by measuring the distance from the

Trendelenburg test (positive)

Source: University of California, San Francisco, Sports Medicine.

palpated anterior superior iliac supine to the medial or lateral malleolus on the same leg using a tape measure. Similarly, the opposite side can be measured and the measured lengths on both sides compared.

An apparent leg length difference can be assessed with the patient in the supine position by measuring the distance from the xiphisternum (the prominence immediately below the breastbone or sternum) to the medial malleolus.

Positive Findings. A difference of more than 1 centimeter is considered of concern for a leg length discrepancy. There may be some error in measurement.

How Good Is the Test? There is no sensitivity and specificity for these measurement tests for leg length discrepancy. The reliability of the measurements between examiners is excellent, though within-examiner reliability is only very good.

Special Tips for Improving Accuracy. If there is suspicion about a leg length discrepancy, especially a true leg length discrepancy, the best test to verify it is a standing anteroposterior (AP) X-ray of the lower extremities from the hip to the ankles, referred to as a scanogram. If there is concern about scoliosis or pelvic asymmetry, scoliosis or pelvis X-rays can be ordered.

Palpation

During the examination of the hip, it is important to feel the anatomical strucutures around the hip and pelvis to see if there are any symptoms. Typically, structures around the hip are tender to direct pressure if they are injured or subject to overuse or overload, often in compensation for problems at the knee, ankle, or the spine. Important landmarks to palpate on the pelvis include the anterior superior iliac spine (ASIS), the posterior superior iliac spine (PSIS), and the pubic symphysis. The examiner should be familiar with the anatomy to be able to isolate specific structures while palpating. The sacroiliac joints and the lumbar spine should be routinely checked in patients with hip complaints.

Palpation of the anterior superior iliac spine

Source: University of California, San Francisco, Sports Medicine.

Anterior Structures

Bony landmarks to palpate on the pelvis anteriorly include the ASIS, the pubic rami (superior and inferior), and the pubic symphysis. The hip joint must be palpated deep in the anterior femoral triangle. It is very difficult to palpate the actual bony structures of the hip since there are other soft tissue structures overlying the joint itself.

The hip flexor is a common cause of anterior hip pain and will typically present with pain deep in the anterior femoral triangle. At times, a click or clunk can be palpated in the front of the hip, especially when the patient flexes and then extends the hip, referred to as an "internal snapping hip" because of its proximity to the hip joint.

Lateral Structures

The lateral greater trochanter is a common area for complaint. In this area, several structures can cause pain, including the gluteus medius and minimus tendon insertions and the greater trochanteric bursa, often resulting in chronic symptoms when they are inflamed. The tensor fascia lata is also another soft tissue structure that is palpable over the greater trochanteric area. Some patients have a clicking sensation laterally when they walk that occurs when the tensor fascia lata snaps over the greater trochanter, referred to as an "external snapping hip."

Palpation of the greater trochanter

Source: University of California, San Francisco, Sports Medicine.

Posterior Structures

Posteriorly, common areas of tenderness include the sacroiliac joints, the coccyx, and the ischial tuberosities, where the hamstring tendons insert. The piriformis is another muscle that can present with activity-related buttock pain. There may be signs of pain or spasm involving the piriformis, which runs from the sacrum to the greater trochanter. Firm pressure needs to be applied when palpating these structures since they lie deep to the soft tissues.

Standing Flexion Test

The standing flexion test assesses the movement between the lumbar spine, pelvis, and hips, specifically focusing on the movement near the sacroiliac joints.

Description of the Maneuver. The examiner is positioned behind the standing athlete. Using the thumbs, the PSIS of each ilium is palpated. These are found at the end of the iliac crest, close to the superior aspect of the sacrum. Oftentimes, there is a dimple overlying the PSIS on each side that is visible on inspection. With the thumbs positioned in a relaxed manner over the PSIS and applying light pressure, the examiner asks the athlete to slowly flex forward or reach toward his or her toes without bending at the knees. The examiner's thumbs will move along with the PSIS. The amount of movement is subjectively determined and compared from side to side.

Standing flexion test

Source: University of California, San Francisco, Sports Medicine.

Positive Findings. Unequal movement of the thumbs during full flexion of the spine suggests abnormal movement at the sacroiliac joints. The thumbs are expected to move superiorly and forward as the iliums rotate forward (nutate).

How Good Is the Test? The reliability of this test is poor between observers. The test displays low sensitivity and moderate specificity.

Special Tips for Improving Accuracy. The presence of scoliosis can affect the motion of the sacroiliac joints due to rotational abnormalities at the lumbar spine.

The "dimples of Venus," similar to the dimples near the buttocks of the famous statue, are usually above the PSIS.

Range of Motion

The examination of the range of motion at the hip is most easily performed with the patient in a lying position. The typical range of motion of the hip with the patient lying on his or her back during the exam, or supine, includes flexion 120° to 130°, extension 15° to 30°, adduction 25° to 30°, and abduction 30° to 50°. Restricted movement in one direction, especially internal rotation, is usually related to the presence of osteoarthritis. Loss of motion in three directions is indicative of osteoarthritis of the hip or other hip joint problem.

To check the range of motion in the hip in the supine position, the examiner can flex the athlete's hip and knee to 90° each. Grasping the heel, the hip can be rotated on the axis of the femur either clockwise or counterclockwise. When the foot is turned out laterally, the hip is internally rotated. When the foot is turned inward, as when crossing one's leg while sitting, the hip is externally rotated. Typical range of motion of the hip with external

Hip range of motion (external rotation)

Source: University of California, San Francisco, Sports Medicine.

Hip range of motion (neutral)

Source: University of California, San Francisco, Sports Medicine.

Hip range of motion (internal rotation)

Source: University of California, San Francisco, Sports Medicine.

Staheli method (external rotation)

Source: University of California, San Francisco, Sports Medicine.

Staheli method (internal rotation)

Source: University of California, San Francisco, Sports Medicine.

rotation is approximately 40° to 60°, and internal rotation is around 30° to 40° from the neutral (midline). Checking passive internal rotation of the hip is almost always the best range-of-motion test to assess for significant problems involving the hip joint.

Staheli Method (Prone)

A very good way to assess rotational hip range of motion is to examine the patient in the prone position, lying face down. This immobilizes the pelvis while checking range of motion of the hips. The examiner asks the athlete to lie face down on the table, keeping the knees together. The examiner then can bend each knee to 90° and then allow the lower leg to rotate inward (external rotation) or outward (internal rotation). Typical range of motion of the hip with external rotation is approximately 40° to 60°, and internal rotation is around 30° to 40° from the neutral (midline). The reproducibility of this measurement is high. This is also referred to as the *Craig test*.

Special Tests: Labral Tests

The examiner should perform enough tests to confirm suspected injuries. Examiners should master at least one or two tests from each group and learn how to do them well before making the diagnosis.

Labral Impingement Test

The labral impingement test for the hip is a provocative maneuver to assess for a labral tear of the hip or other internal derangement in the joint.

Description of the Maneuver. The examiner has the athlete lie supine on the examination table. The examiner passively flexes the hip to 90° with the knee at 90° of flexion (see image part A) and fully rotates the hip internally (see image part B). The

Labral impingement test part A

Source: University of California, San Francisco, Sports Medicine.

Labral impingement test part B

Source: University of California, San Francisco, Sports Medicine.

hip is then returned to the neutral position of rotation and adducted. It is then internally rotated again in the adducted position.

Positive Findings. This test is positive if the pain is reproduced deep in the groin with either maneuver. Typically, the test is more painful with the hip adducted and internally rotated than with the hip at neutral, 0° adduction, and internally rotated.

How Good Is the Test? For the labral impingement test, sensitivity was moderate, specificity was high, and interrater reliability was moderate.

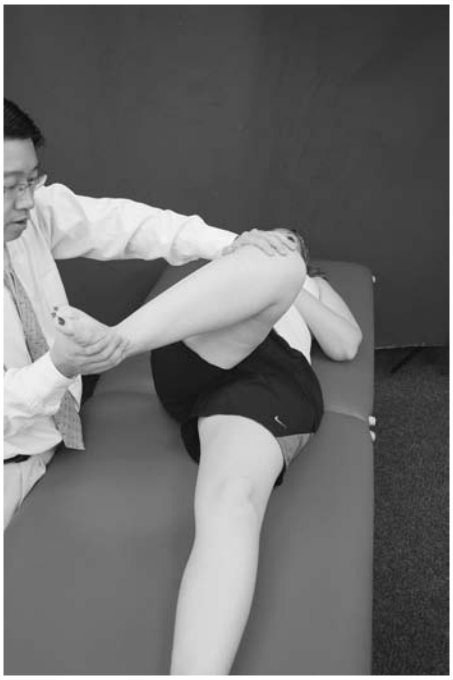
Special Tips for Improving Accuracy. Many patients complain of pain near the gluteal muscle insertions with internal rotation of the hip. The pain associated with the hip joint is classically in the groin area and occasionally deep in the buttock if the posterior aspect of the joint is affected.

Labral Stress Test (Hip Scour Test)

This test checks for a labral tear of the hip or other internal derangement in the joint.

Description of the Maneuver. The examiner has the athlete lie supine on the examination table. The examiner passively flexes the hip to 90° with the knee at 90° of flexion. The hip is then slowly, passively circumducted, first in the clockwise and then in the counterclockwise direction, taking the hip fully into internal and external rotation.

Positive Findings. This test is positive if the pain is reproduced deep in the groin with any of these maneuvers. Typically, the test is more painful with the hip adducted and internally rotated than with the hip at neutral, 0° adduction and internally rotated, though posterior hip pain can be painful often with abduction and external rotation of the hip.



Labral stress test part A

Source: University of California, San Francisco, Sports Medicine.

Labral stress test part B

Source: University of California, San Francisco, Sports Medicine.

Labral stress test part C

Source: University of California, San Francisco, Sports Medicine.

How Good Is the Test? There are minimal data on the sensitivity, specificity, and reproducibility of this test.

Flexibility Tests

Thomas Test (Snapping Hip Test)

The Thomas test assesses for flexibility of the hip flexor or iliopsoas. This test can identify a hip flexor contracture or snapping hip flexor tendon.

Description of the Maneuver. The examiner has the athlete lie in the supine position at the end or side of the table so that the patient's leg can drop off the table. Both knees are flexed toward the chest, and the nontested leg is held by the patient to immobilize the pelvis and the lumbar spine. The tested leg is then allowed to passively extend at the hip.

Positive Findings. If the leg cannot reach the table and remains in a flexed position at the end of the

Thomas test

Source: University of California, San Francisco, Sports Medicine.

test, it suggests a tight hip flexor tendon/muscle. Normally, the leg can be brought down to the table level or extended beyond.

How Good Is the Test? The Thomas test had moderate intra- and interrater reliability.

Special Tips for Improving Accuracy. The examiner can keep his or her thumb palpating the anterior iliac spine during the test for motion at the pelvis when the hip flexor is being stretched.

Ely Prone Knee Flexion Test

The Ely test assesses the flexibility of the quadriceps muscle and tendons, specifically the rectus femoris.

Description of the Maneuver. The athlete lies prone on the examination table. Keeping the leg in the neutral position without adduction and abduction, the examiner passively flexes the athlete's knee. The angle of knee flexion is measured and compared on both knees.

How Good Is the Test? The Ely test was shown to have moderate sensitivity and moderate to high specificity. Intra- and interrater reliability was moderate.

Ely test

Source: University of California, San Francisco, Sports Medicine.

Ober Test

This test assesses the tightness of the tensor fascia lata and iliotibial band, located at the lateral hip and knee, respectively.

Description of the Maneuver. The athlete lies on his or her side on the examination table. Keeping the leg relaxed and slightly flexed forward at the hip, the examiner passively abducts the athlete's leg with the knee bent no more than 90°. Some examiners keep the knee extended straight. The abducted leg is then slowly extended and then allowed to passively fall in adduction. The spine should remain perpendicular to the exam table at all times.

What Is a Positive Test? Normally, the knee will drop toward the table. A positive test occurs when the leg cannot reach a level that is at least parallel to the table. Often, the leg will remain abducted due to tightness or a contracture of the tensor fascia lata and iliotibial band.

Reliability. Interrater ICC (intraclass correlation coefficients) = 0.90.

Ober test

Source: University of California, San Francisco, Sports Medicine.

Special Tips for Improving Accuracy. The test cannot be performed accurately when the knee is flexed too far, for example, past 90°, as tightness of the quadriceps and hip flexor can affect the tightness observed.

Piriformis Test

The piriformis test assesses pain that is associated either with the piriformis muscle or with the adjacent sciatic nerve.

Description of the Maneuver. The athlete lies on the side with the upper leg flexed forward across his or her body. The examiner can support the body with one hand while applying a downward pressure to the knee. Symptoms can be further aggravated by asking the athlete to externally rotate the hip in this position against resistance.

What Is a Positive Test? Piriformis syndrome can present with pain in the buttock with radiating pain down the leg if the sciatic nerve is affected by the piriformis muscle.

Gaenslen test part A

Source: University of California, San Francisco, Sports Medicine.

Gaenslen test part B

Source: University of California, San Francisco, Sports Medicine.

Provocative Tests

Gaenslen Test

The Gaenslen test is a provocative test for hip flexor tendinopathy or sacroiliac joint pathology. This test can help identify a hip flexor contracture or snapping hip flexor tendon, or it can stress the sacroiliac joint.

Description of the Maneuver. The examiner positions the athlete in the supine position at the end or side of the table so that the patient's leg can drop off the table. Both knees are flexed toward the chest, and the nontested leg is held by the patient to immobilize the pelvis and the lumbar spine. The tested leg is then allowed to passively extend at the hip. By placing one hand on each knee, the examiner then passively hyperextends the hip and hyperflexes the opposite hip. The hip strength can be recorded on a scale of 1 to 5.

Positive Findings. Reproduction of the patient's hip pain deep to the anterior aspect of the hip predominantly suggests a hip flexor tendinopathy or a primary joint pathology.

How Good Is the Test? The test is moderately sensitive and has low to moderate specificity for sacroiliac joint pain.

Reliability. Test-retest kappa statistic (k) = 0.58; specificity: right 71%, left 77%; sensitivity: right 53%, left 50%; odds ratio: positive likelihood ratios, right 1.84, left 2.21; negative likelihood ratios, right 0.66, left 0.65.

Special Tips for Improving Accuracy. The examiner can keep his or her thumb palpating the anterior iliac spine during the test for motion at the pelvis when the hip flexor is being stretched.

FABER Test (Patrick Test or Figure-Four Test)

The FABER (*f*lexion, *ab*duction, *e*xternal *r*otation) test is a provocative stress test that reproduces symptoms of intraarticular hip pathology, such as osteoarthritis, articular cartilage injuries, or labral tears.

Description of the Maneuver. The athlete is supine on the examination table, and the hip is placed in flexion, abduction, and external rotation (FABER), which is referred to as the figure-four position. The patient ends up crossing his or her leg with the foot just above the opposite knee. The examiner then applies a downward force to the crossed leg at the knee, externally rotating the hip further.

FABER test

Source: University of California, San Francisco, Sports Medicine.

Positive Findings. A positive test is reproduction of the athlete's hip pain, which is typically in the anterior groin or deep posterior buttock.

How Good Is the Test? The FABER test is highly sensitive for intraarticular pathology. It has high reliability on retesting.

Slump Test

The slump test is a neurodynamic test, placing mechanical stress, traction, or compression on neurologic tissues in the lumbar spine. This test looks for sciatica and can be performed in conjunction with the straight leg raise (SLR) test and indirect straight leg raise test. For these tests to be positive, they must reproduce the patient's symptoms regardless of discomfort and pain.

Description of the Maneuver. The athlete sits on the table with his or her hands behind the back. The patient is asked to "slump forward" at the lumbar and thoracic spine while keeping the head in a neutral position. The examiner can apply pressure across the shoulders to maintain thoracolumbar spine flexion. The patient is then asked to fully flex the neck, "chin to chest." The examiner applies overpressure to the cervical spine to maintain cervicothoracolumbar flexion. The examiner then holds the foot in dorsiflexion, and the patient is asked to actively straighten his or her knee, or the examiner passively extends it. The test is then repeated with other leg.

Positive Findings. The test is positive if the patient's symptoms are reproduced at any stage, including shooting pain from increased tension in the spinal cord and sciatic nerve. The patient's symptoms often decrease with neck extension. The athlete may become apprehensive about being placed in the slump test position and may lean backward to avoid further flexion of the spine.

How Good Is the Test? The reliability between examiners for this test is high.

Slump test

Source: University of California, San Francisco, Sports Medicine.

Special Tips for Improving Accuracy. If the patient is unable to fully extend the knee because of pain, he or she is allowed to actively extend the neck for relief, allowing further knee extension.

Anthony Luke

See also Musculoskeletal Tests, Spine

Further Readings

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Musculoskeletal Tests, Knee

The musculoskeletal tests in this entry are used to diagnose common injuries around the knee. The knee is one of the most commonly injured joints, especially in sports that involve a lot of running and jumping. The most common knee complaints typically involve the patellofemoral joint. The knee takes a lot of stress, especially when bending. Studies have shown that the forces at the knee joint can reach three times the body weight when the knee is bent, such as when going upstairs, and up to six to seven times the body weight when the person is in a full squat position. Internal derangement of the knee refers to a variety of damaged structures that can be injured within the knee, for example, meniscal cartilage tears or loose bodies. Ligament tears often present with pain and instability during function. A higher degree of tearing of the ligament typically results in more instability symptoms. The knee serves as an important point of transmission between the ankle and the hip. As such, knee injuries are among the most common complaints encountered in sports medicine.

Examination of the Knee

Observation: Knee Alignment

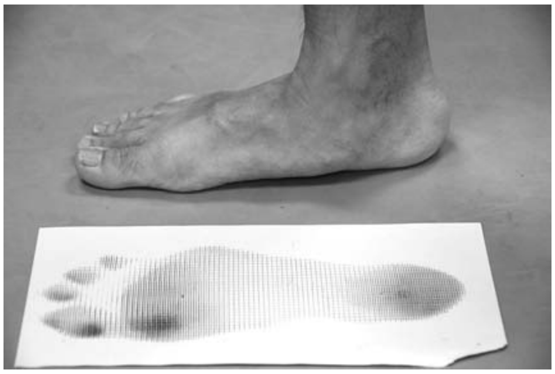
The examination of the knee includes assessment of posture and lower extremity alignment. The alignment at the knees can be quickly screened by asking the athlete to stand with the ankles together, observing the knees. If there is a wide space between the knees when the athlete stands with the feet together and the athlete appears to be "bowlegged," the athlete has *genu*

Genu varum

Source: University of California, San Francisco, Sports Medicine.

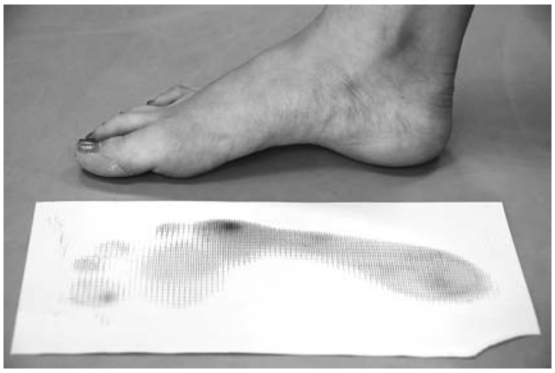
Femoral anteversion

Source: University of California, San Francisco, Sports Medicine.



Pes planus

Source: University of California, San Francisco, Sports Medicine.



Pes cavus.

Source: University of California, San Francisco, Sports Medicine.

varum, indicating that the lower leg angles inward after the knee (toward the midline). Similarly, if the athlete appears "knock-kneed" and has difficulty putting the feet together due to the proximity of the knees, it is called *genu valgus* alignment. With the feet together pointing forward, if the kneecaps point inward, it is called "squinting patellae" and often represents a rotational malalignment at the hips called *femoral anteversion,* where the hips are angled such that the knees and lower leg rotate inward. It is important to always check the hip joint when evaluating knee injuries. The hip may refer pain to the knee.

Observation: Foot Arch Alignment

The athlete can then stand with the ankles a shoulder width apart. When the athlete goes on his or her toes, the arch of the foot can be assessed. Typically, with individuals who have a flexible foot arch, the arch becomes maximal as they go on their toes. As the athlete comes down, the arch can be observed to see if it collapses. If the arch is lost, the athlete's foot is termed *pronated*. If this is severe, it may create a completely flat foot, which is termed *pes planus*. A very high-arched foot is referred to as *pes cavus*.

The athletes can be observed performing functional activities such as walking, hopping, squatting, walking on their heels, and walking on their toes to test the function of the knees and other joints in the lower extremities.

Observation: Kneecap Position and Swelling

Milk or Bulge Sign

The knee is observed easily when the athlete is lying down. Swelling inside the knee joint, referred to as *effusion*, can be observed over the medial and lateral aspects of the kneecap, especially near the top area of the knee, known as the suprapatellar pouch. It is useful to compare both knees. When one has swelling in the knee, it is difficult to see the normal indentations or "dimples" around the kneecaps. To palpate for swelling in the knee, one can stroke the medial aspect of the knee, pushing the fluid inside the knee into the suprapatellar pouch above the knee. By pushing on the lateral aspect from a superior to inferior direction, one can *milk* fluid back into the knee from above. If a *bulge* of fluid forms on the medial aspect of the knee causing a fluid wave, suspect a joint effusion, which suggests a problem causing swelling within the knee joint.

Medial milking sign

Source: University of California, San Francisco, Sports Medicine.

Lateral milking sign

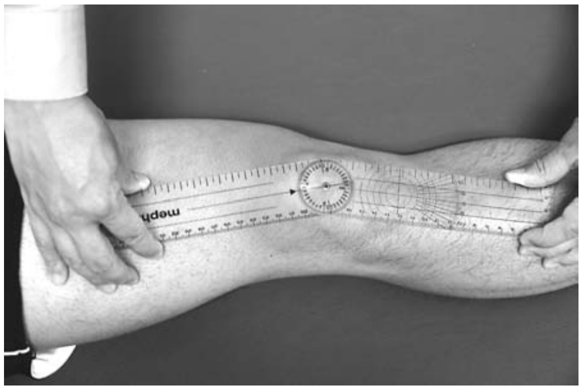
Source: University of California, San Francisco, Sports Medicine.

Patellar Tap

A method to assess for fluid in the knee involves using one hand to push the fluid in the superior pouch or capsule of the knee. If there is more joint fluid under kneecap the, by using the other hand, you can feel that the kneecap is floating on the fluid. Normally, the kneecap rests on the femur (thigh) bone, and there is no movement when pushing directly posterior on the kneecap.

Bursal Swelling

There are several bursas around the knee. These serve to provide protection of soft tissues near an area of bony prominence, which can lead to excessive friction during activity, resulting in pain and swelling. Two common areas for swelling around the knee include the prepatellar bursa, usually found immediately on top of the kneecap, as well as the pes anserine bursa, usually found over the medial aspect of the proximal tibia (shinbone). These swellings can be mild or, in some cases, very large. Fortunately, they often resolve without any medical intervention.



Q angle

Source: University of California, San Francisco, Sports Medicine.

Q Angle

The *Q angle* is the angle measured from the front of the pelvis, center of the kneecap and the tibial tubercle (front bump on the proximal tibia/shin). After puberty, the Q angle normally ranges between 13° and 18°. A Q angle less than 13° is often associated with patella alta (see below). An angle greater than 18° is associated with femoral anteversion. A high Q angle may be found in individuals who complain of kneecap pain.

Patella Alta

Patella alta means a high-riding kneecap. Some individuals naturally have a high position for the kneecap, which may make the kneecap fairly loose side to side during examination. If the kneecap is positioned higher after an acute injury where the joint is hyperflexed, then a patellar tendon rupture may be suggested. From the side view of the knee, a patella alta may demonstrate the "camel" sign, where there are two bumps seen involving the kneecap and the proximal tibia, with the gap being the area of the patellar tendon rupture.

Patella Baja or Infera

Patella baja or *infera* means low kneecap. The kneecap is positioned lower in these athletes, which may result in pain symptoms. Following an acute trauma where the knee is hyperflexed, if a new patella baja is seen, the potential injury that the athlete has sustained is a quadriceps tendon tear.

Palpation

During the examination of the knee, it is important to feel the anatomical structures of the knee to see if they have been injured. Typically, tenderness on application of direct pressure suggests damage to the structures around the knee, such as the joint surfaces of the kneecap, femur (thigh), and tibia (shin), as well as the muscles and tendons around the knee.

Patellar Mobility

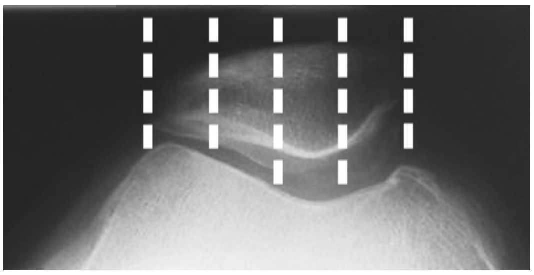
Patellar mobility is determined by passive medial and lateral movement. The patella can be divided into quadrants. A patella is hypomobile when it moves less than one quadrant on medial or lateral glide. A hypermobile patella is illustrated by glide of more than two quadrants (one half of the patellar width).

Patellar Tilt

It should also be noted whether the patella tilts or rotates when it is pushed medially or laterally.

Lateral patellar glide

Source: University of California, San Francisco, Sports Medicine.



X-ray of knee with quadrants

Source: University of California, San Francisco, Sports Medicine.

If the medial structures are too tight, the patella will tilt up when pushed laterally. If the lateral structures are too tight, the patella will tilt up when pushed medially.

Patellar Crepitus

A crunching sensation, or *crepitus,* can be felt under the kneecap while flexing and extending the knee. This can represent degenerative changes in the joint surfaces or maltracking of the kneecap with movement.

Joint Line Tenderness

The joint line can be felt using one's index finger. The joint line can be felt at the top of the shin, where one's finger drops onto a soft area between the bones. One can extend and flex the knee to confirm the presence of the joint line. The meniscal cartilage and articular cartilages are felt when palpating the joint line. Local tenderness may suggest injury to these cartilage structures.

Range of Motion

The examination of range of motion at the knee is most easily performed with the patient in a lying position. Full knee flexion is approximately 135° (range 120°–150°). Hyperextension may occur, especially in women (range 0°–15°). A goniometer is a joint angle–measuring tool that can measure range of motion. The greater trochanter (hip reference), lateral joint line (knee), and lateral malleolus (ankle) are used as reference landmarks to check range of motion in the knee.

The "Locked" Knee

Worrisome signs include a "locked" knee that lacks full extension compared with the other side because it suggests an internal derangement in the knee, for example, large meniscus tears, a ligament tear, or a loose body/bone chip.

Extensor Mechanism Disruption

The inability to extend the knee against gravity in the lying down position suggests an injury to the extensor mechanism of the knee, for example, quadriceps tendon tear, patellar fracture, or patellar tendon injuries.

Special Tests: Ligament Tests

The examiner should perform enough tests to confirm suspected injuries. Examiners should master

Knee flexion

Source: University of California, San Francisco, Sports Medicine.

Knee extension

Source: University of California, San Francisco, Sports Medicine.

at least one or two tests from each group and learn how to do them well in order to make a correct diagnosis.

Ligaments are located between two bones to provide stability to joints. Following injury to a ligament, athletes may complain of joint instability and giving way symptoms. The examiner should test the normal knee first to establish the baseline stability inherent to the athlete's joint. It is important for clinicians to use the same starting position and the same amount of force for both limbs while performing stress tests on ligaments. The muscles must be relaxed throughout the ligament tests. If the ligament is intact, there should be an abrupt end point when it is tested. A soft end point usually represents injury.

Lachman Test

The Lachman test examines for a tear or laxity of the anterior cruciate ligament (ACL).

Description of the Maneuver. The patient is placed in a supine position. The examiner performs the test on the same side of the affected knee with the knee at 20° to 30° of flexion. Fixing the femur with one hand, the examiner lifts the tibia forward with the other hand. The foot should be slightly externally rotated, with the anterior force applied near the posteromedial aspect of the proximal tibia. One lifts the shin forward with approximately 15 lb (pounds) of force (i.e., to lift a 15-lb weight).

Positive Findings. A positive finding is increased anterior movement of the tibia on the femur compared with the normal side. This is typically more than 3 millimeters (mm) of movement.

How Good Is the Test? A summary of the literature suggests that the Lachman test has high sensitivity, high specificity, and moderate reproducibility.

Special Tips for Improving Accuracy. ACL testing is ideally done at 20° to 30° of knee flexion because that is the position where the joint capsule and its attachments give the least resistance. For large legs and small hands, the examiner can cup one hand and fix the femur while using the other hand and wrist wrapped behind the tibia to pull the tibia forward. The examiner should make sure the pulling force applied to the leg is perpendicular to the plane of the tibia.

Lachman technique

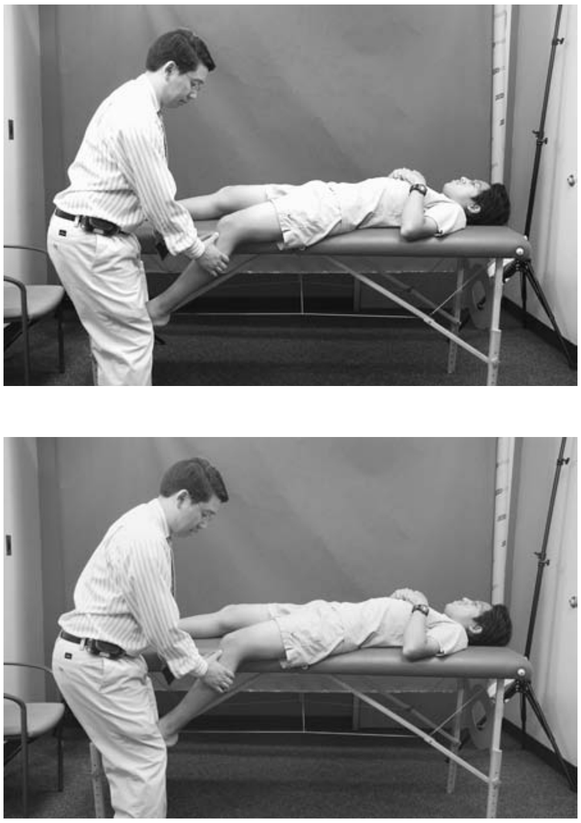
Source: University of California, San Francisco, Sports Medicine.

Drop Lachman Test

The drop Lachman test is a variant of the Lachman test and examines for a tear or laxity of the ACL.

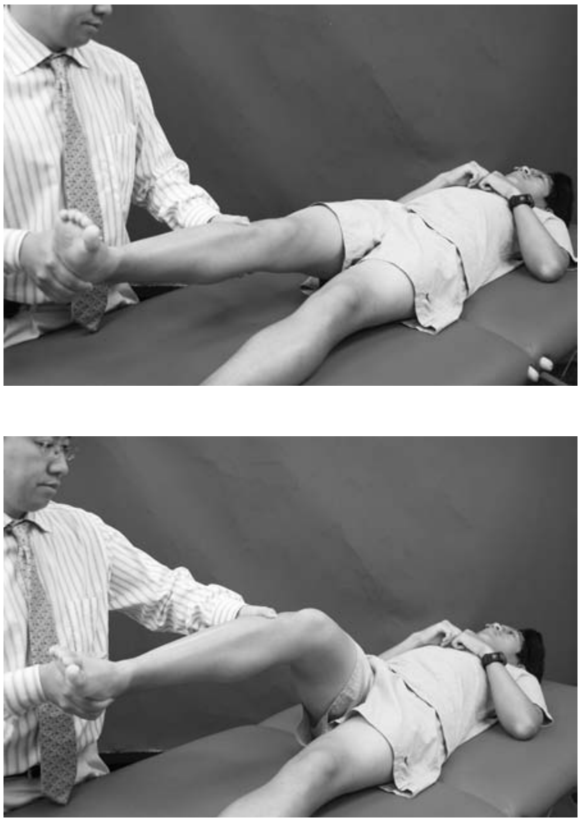
Description of the Maneuver. The patient lies supine with the leg abducted off the side of the table and flexed to 20° to 30°. The foot is stabilized between the examiner's legs. Both hands can be used to pull the tibia forward, or one can use the free hand to anteriorly direct the tibia.

Positive Findings. A positive finding is increased anterior movement of the tibia on the femur compared with the normal side. This is typically more than 3 mm of movement.



Drop Lachman technique

Source: University of California, San Francisco, Sports Medicine.



Pivot shift

Source: University of California, San Francisco, Sports Medicine.

How Good Is the Test? The drop Lachman test has high sensitivity, better than the classic Lachman test.

Special Tips for Improving Accuracy. The athlete's thigh is stabilized by the table as the leg drops off, reducing muscle spasm and making the leg more relaxed during the examination.

Pivot Shift Test (Test of MacIntosh)

The pivot shift test checks for functional instability of the ACL. The test aims to recreate the "giving way" instability at the knee that athletes describe during sports activity. This test was originally described by Galway, Beaupre, and MacIntosh in 1972.

Description of the Maneuver. To perform the pivot shift exam, the knee is placed at 10° to 20° of flexion. The tibia is internally rotated, and valgus stress is applied over the lateral aspect of the proximal femur. The knee is slowly flexed under stress.

Positive Findings. The knee spontaneously reduces when flexed, usually around 40°, often with a noticeable clunk.

How Good Is the Test? The sensitivity for the pivot shift is moderate (though the range is from low to high in the literature), and the specificity is high.

Special Tips for Improving Accuracy. A grading system from 1 to 3 can be used to describe the movement that is seen at the knee during the pivot shift test. A Grade 1+ suggests a slight slide, associated at times with a sense of grinding in the lateral compartment. A Grade 2+ test demonstrates a distinct jump. A Grade 3+ test shows gross instability on testing, with locking occurring during the movement. It is unlikely that a patient with a 2+ or 3+ pivot shift will be able to return to unlimited sports activity. Athletes with a negative or 1+ pivot shift and the presence of an end point on Lachman testing rarely complain of giving way symptoms.

Anterior Drawer Test

The anterior drawer test examines for a tear or laxity of the ACL.

Description of the Maneuver. With the athlete lying on his or her back, the knee is bent as close to 90° as possible with the foot resting on the table. The examiner places both hands behind the tibia and pulls the tibia forward, using a force between 15 and 20 lb. The test can also be performed with the foot externally rotated (turned out) to 15°.

Positive Findings. A positive test is increased anterior movement of the tibia on the injured side compared with the noninjured side. Up to 3 mm of forward movement of the tibia is considered normal. The grading for the test is as follows: Grade 1 = 5 mm, Grade 2 = 5 to 10 mm, and Grade 3 > 10 mm.

How Good Is the Test? A summary of the literature suggests that this test has moderate sensitivity and high specificity. The test is not as sensitive a test as the Lachman or as specific as the pivot shift.

Special Tips for Improving Accuracy. The anterior drawer test has reduced sensitivity, especially after an acute injury, due to the protective spasm of the hamstring muscles, any large swelling in the knee, and any effects of the posterior horn of the medial meniscus.

Anterior drawer test

Source: University of California, San Francisco, Sports Medicine.

Valgus Stress Test

The valgus stress test checks for medial joint laxity, which usually indicates an injury to the medial collateral ligament (MCL).

Description of the Maneuver. The athlete lies on his or her back. The examiner positions one hand at the joint line on the outside part of the knee while the other fixes the ankle on the affected side. The examiner flexes the knee between 20° and 30° and applies a medial or valgus force to the knee. Approximately 15 to 20 lb of force is applied during the test. The test can be repeated at 0° with the knee in full extension to test the MCL as well as the posterior medial capsule.

Positive Findings. A positive test demonstrates increased medial joint laxity compared with the unaffected side. A grading system from 1 to 3 can be used that is based on the amount of joint space opening (Grade 1 = 5 mm, Grade 2 = 5–10 mm, and Grade 3 >10 mm).

How Good Is the Test? The reproducibility between observers (Kappa) is moderate to high.

Special Tips for Improving Accuracy. Fixing the ankle and pushing medially with the hand at the knee allows the examiner to apply the force to the knee easily due to the leverage of the long bone of the shin. In an acute MCL injury, there may be substantial loss of motion and pain so that the athlete may not wish to move the leg in extension or flexion. These are usually higher-grade MCL tears. This appearance of an acute knee injury, referred to as "pseudolocking," can be confused with more damage within the knee, though it is only the MCL.

Valgus stress test

Source: University of California, San Francisco, Sports Medicine.

Varus stress test

Source: University of California, San Francisco, Sports Medicine.

Varus Stress Test

The varus stress test checks for joint laxity on the outside of the knee, which usually represents an injury to the lateral collateral ligament (LCL).

Description of the Maneuver. The athlete lies on his or her back. The examiner positions one hand at the joint line on the outside part of the knee while the other fixes the ankle on the affected side. The examiner flexes the knee between 20° and 30° and applies a lateral or varus force to the knee. This can be done either by reaching over the top of the knee or by approaching the patient from the inside aspect of the knee with the leg out to the side. Approximately 15 to 20 lb of force is applied during the test. The test can be repeated at 0° with the knee in full extension.

Positive Findings. A positive test demonstrates increased lateral joint laxity compared with the unaffected side. A grading system from 1 to 3 can be used that is based on the amount of joint space opening (Grade 1 = 5 mm, Grade 2 = 5–10 mm, and Grade 3 > 10 mm).

How Good Is the Test? The sensitivity of the varus stress test is low, though there are no studies on its efficacy.

Special Tips for Improving Accuracy. Fixing the ankle and pushing laterally with the hand at the knee allows the examiner to apply force to the knee easily due to the leverage of the long bone of the shin. If the leg opens on varus stress testing, check the ACL, PCL, and posterolateral corner tests very carefully as the LCL is not commonly torn in isolation.

Posterior Sag Sign

The posterior sag sign is an observational test looking for a tear in the posterior cruciate ligament (PCL). When the PCL is torn, the shin appears to sag back on one side due to posterior shift of the tibia/shin.

Description of the Maneuver. The athlete lies on his or her back with both hips flexed to 45° and knees to 90°. The examiner then looks perpendicularly across the knees at the front of the shins.

Positive Findings. A positive sag sign occurs when there is an absent tibial tubercle or the prominence at the top of the shin is more obvious on one side than on the other.

How Good Is the Test? The posterior sag sign has a moderate to high sensitivity and a high specificity.

Special Tips for Improving Accuracy. This test should be considered with special attention to the history, because the PCL needs to have the anterior to posterior force and trauma to the knee either directly or by falling directly on the shin. Pulling forward on the shin can often reduce the sag, placing the knee in its original position.

Posterior Drawer Test

The posterior drawer test is a stress test looking for a tear in the posterior cruciate ligament (PCL).

Description of the Maneuver. With the athlete lying on his or her back, the knee is bent as close to 90° as possible with the foot resting on the table. The examiner places both hands behind the tibia and pushes backward on the proximal shin/tibia, looking for instability backward, using a force between 15 and 20 lb.

Positive Findings. A positive posterior drawer test involves further backward motion when a force is applied posteriorly on the upper shin on one side rather than on the other (posterior translation of the tibia).

How Good Is the Test? The posterior drawer test has moderate to high sensistivity.

Posterior sag sign

Source: University of California, San Francisco, Sports Medicine.

Posterior drawer test

Source: University of California, San Francisco, Sports Medicine.

Special Tips for Improving Accuracy. A PCL injury can give false-positive ACL laxity because pulling the leg forward may actually reduce the knee from its new posterior position. Therefore, one should take special notice of any posterior sag sign in the knee before the test is performed. Applying a posterior force to the tibia with the knee flexed 80° and the tibia externally rotated 15° can also stress the posterolateral corner of the knee.

Dial Test (Posterolateral Drawer Test)

The dial test assesses for laxity in the posterolateral structures of the knee (also known as the posterolateral corner [PLC]).

Description of the Maneuver. The athlete lies face down on the exam table. The examiner positions the athlete with both knees together and places the knees at 30° of flexion. Grasping the heels on both sides, the examiner turns both feet outward (external rotation), turning the shins outward like a dial. The test is then performed with the knees at 90°, again turning the shins outward. The examiner takes note of the angle of the foot in relation to the midline, before and after turning the feet.

Positive Findings. A positive dial test occurs when one foot turns 10° more than the opposite side. When a positive test occurs at 30°, it suggests that the structures of the PLC have been damaged. If the test is positive at 90°, it suggests that the structures of the PLC as well as the PCL have been damaged.

Meniscal Tests

Because menisci are avascular and have no nerve supply on their inner two thirds, there can be little or no pain or swelling with injury. The history is often very useful, with reports of clicking or locking, especially in deep squats. Joint line pain or tenderness may also be present. Most tears occur in the posterior aspects of the menisci.

Joint Line Tenderness

Description of the Maneuver. The athlete's knee is passively placed in maximal flexion by the examiner while the athlete is lying on his or her back. The knee is flexed to 90°. The tibia is felt and then dropped into the joint space. The finger or thumb is moved sequentially along the joint line medially and laterally.

Positive Findings. A positive sign is reproduction of the patient's localized pain over the joint line.

How Good Is the Test? The sensitivity in palpating the joint line is high, and the specificity is low.

Special Tips for Improving Accuracy. Fractures that are positioned near the joint line of the knee can be painful with the application of direct pressure

Dial test at 45°

Source: University of California, San Francisco, Sports Medicine.

Dial test at 90°

Source: University of California, San Francisco, Sports Medicine.

Medial joint line palpation

Source: University of California, San Francisco, Sports Medicine.

Extension block hyperextension

Source: University of California, San Francisco, Sports Medicine.

(e.g., MCL/LCL injury, osteoarthritis of the joint surface, and bone bruise). If an area of swelling is noted along the joint line, it can suggest the presence of a meniscal cyst.

Hyperflexion

Description of the Maneuver. The athlete's knee is passively placed in maximal flexion by the examiner.

Positive Findings. A positive sign is reproduction of the patient's localized pain over the joint line.

Knee hyperflexion

Source: University of California, San Francisco, Sports Medicine.

How Good Is the Test? The sensitivity and specificity are moderate.

Extension Block Hyperextension

Description of the Maneuver. The athlete's knee is passively placed in maximal extension by the examiner. The examiner can grasp the knee with one hand above the patella and push the knee gently into extension.

Positive Findings. A positive sign is reproduction of the patient's localized pain in the joint line.

How Good Is the Test? The sensitivity was moderate, and the specificity was high.

McMurray Test, Classic

The classic McMurray test checks for meniscal tears or other internal derangement in the knee.

Description of the Maneuver. The athlete lies on his or her back, and the examiner grasps the heel with his or her hand (i.e., the right hand and right heel). The other hand can be placed on the athlete's knee with the thumb and fingers over the joint line. The leg is then moved from full, acute flexion to full extension with the foot in full internal and then

McMurray test part A

Source: University of California, San Francisco, Sports Medicine.

Modified McMurray test part A

Source: University of California, San Francisco, Sports Medicine.

McMurray test part B

Source: University of California, San Francisco, Sports Medicine.

Modified McMurray test part B

Source: University of California, San Francisco, Sports Medicine.

full external rotation. In the classic McMurray test, no valgus or varus stress is applied to the knee. Typically, internal rotation of the tibia/shin tests the lateral compartment, and external rotation of the tibia tests the medial compartment (think of the direction of the heel).

Positive Findings. A palpable thud is a positive sign, as well as pain localized to the joint line. When there is a tear in the posterior meniscal cartilage with a loose fragment, the piece will snap when the knee is brought from full flexion and extended.

How Good Is the Test? The test has low to moderate sensitivity, high specificity, and high reproducibility (Kappa), especially when looking for a thud or click, in particular on the medial side.

Special Tips for Improving Accuracy. The laterality of the test is nonspecific, which means that the test can bother a meniscal tear on either side of the knee when rotation occurs. There is no strong association between the rotation, the side on which the symptoms occur, and the side of the tear.

Modified McMurray Test

This is presently the more common way in which the McMurray test is performed to check for a meniscus tear.

Description of the Maneuver. With the patient supine, the hip and knee are bent to 90°. Grasping the heel in one hand and with the other hand over the knee with the thumb and fingers on the joint line, the examiner gently rotates the tibia, with the heel internally rotated and exerting a mild valgus force (for the lateral compartment) and externally rotated and exerting a mild varus force (for the medial compartment).

Positive Findings. A positive sign is pain over the joint line reproducing the patient's symptoms or a painful click along the joint line.

How Good Is the Test? This test has high specificity but low to moderate sensitivity, especially when looking for a thud or click, in particular on the medial side.

Special Tips for Improving Accuracy. The laterality of the test is nonspecific, which means that the test can bother a mensical tear on either side of the knee when rotation occurs.

Thessaly Test

The Thessaly test is a functional test for meniscus tears in the standing position. As bending and twisting movements while weight bearing often reproduce pain from meniscus tears, this test recreates the exacerbating movements.

Description of the Maneuver. The athlete stands on one foot with the foot flat on the floor. The examiner holds the athlete's hands to give support. First, the patient bends on the standing knee to 5° of flexion. The patient then is asked to twist on the knee, internally and externally rotating at the knee rather than at the pelvis or back, checking for reproduction of the pain symptoms. The patient then bends the knee deeper to 20° and again actively twists on his or her knee.

Positive Findings. The twisting movement will reproduce pain in meniscal injury. The pain is typically localized to the joint line. Patients usually have more pain with knee bent at 20° rather than at 5°.

Thessaly test (side view with knee at 20° flexion)

Source: University of California, San Francisco, Sports Medicine.

Thessaly test (patient asked to internally and externally rotate on the flexed knee)

Source: University of California, San Francisco, Sports Medicine.

How Good Is the Test? The sensitivity and specificity of the Thessaly test are high for both medial and lateral meniscus tears. The Thessaly is one of the most useful tests for checking for meniscus tears.

Steinmann Sign

This checks for internal derangement problems in the knee, such as meniscal tears or loose bodies. In children, one can consider osteochondritis dissecans in the differential diagnosis if the patient complains of internal pain.

Description of the Maneuver. With the patient sitting, the examiner internally and externally rotates the tibia with the knee flexed to 90° and dangling off the table. The examiner can do so by grasping the ankle and internally and externally rotating the tibia.

Positive Findings. A positive sign is reproduction of pain over the joint line.

Apley (Grind) Test

The Apley test checks for meniscus tears or other knee internal derangement.

Apley test part A

Source: University of California, San Francisco, Sports Medicine.

Steinmann sign

Source: University of California, San Francisco, Sports Medicine.

Apley test part B

Source: University of California, San Francisco, Sports Medicine.

Description of the Maneuver. The athlete lies face down on the table, and the knee is flexed to 90°. The examiner grasps the ankle and first lifts vertically to distract the knee joint. The lower leg is then internally or externally rotated (distraction). The second part of the test is then holding the heel and pushing down on the shin. Again, the lower leg is then internally or externally rotated (compression).

Positive Findings. A positive Apley test involves reproducing the patient's pain or mechanical catching within the knee.

How Good Is the Test? This test is still commonly taught and practiced, though there are other tests that are better based on sensitivity and specificity. The test has low sensitivity with both compression and distraction maneuvers. The specificity has been shown to be high in some studies.

Special Tips for Improving Accuracy. If the test is used, it should be correlated to the history and the findings of other physical exam maneuvers.

Patellofemoral Tests

Patellar Apprehension Test

The patellar apprehension test checks for side-to-side instability of the kneecap.

Instructions. The examiner has to assess patellar glide at 20° flexion.

Description of the Maneuver. With the athlete lying flat on his or her back, the examiner can grasp the kneecap and push laterally, trying to displace it as far as possible without hurting the patient or causing a dislocation of the kneecap.

Positive Findings. The athlete may contract the quadriceps to avoid subluxation of the patella, or he or she will express apprehension that the kneecap is slipping out of joint.

Patellar apprehension test

Source: University of California, San Francisco, Sports Medicine.

Quadriceps Inhibition Test or Active Compression Test (Clarke Sign)

The Clarke sign reproduces the pain associated with patellofemoral syndrome.

Description of the Maneuver. With the athlete supine, the examiner places one hand over the superior aspect of the patella, holding the kneecap in place with the web space between the thumb and the index finger. The athlete should then contract the quadriceps.

Positive Findings. The pain under the kneecap will be reproduced with the maneuver. The athlete may not be able to sustain the contraction due to pain. The patient may not wish to perform the maneuver due to apprehension of pain.

How Good Is the Test? This test has a high specificity.

Special Tips for Improving Accuracy. If positive, this is often a painful maneuver, thus it is better to perform at the end of the knee examination.

Quadriceps inhibition test

Source: University of California, San Francisco, Sports Medicine.

Functional Tests

One-Leg Hop Test

One-leg hop test is a functional test to check the general functioning of the knee. It is done to test how the athlete can perform a jumping motion on one foot and also to find out if there is any pain while landing. Athletes with significant painful injuries will usually be apprehensive about performing this test, or they may lose their balance or complain of pain during the test.

One-leg hop test

Source: University of California, San Francisco, Sports Medicine.

Anthony Luke

See also Anterior Cruciate Ligament Tear; Iliotibial Band Syndrome; Knee, Osteochondritis Dissecans of the; Knee Injuries; Kneecap, Subluxating; Meniscus Injuries; Osgood-Schlatter Disease; Patellar Tendinitis; Patellofemoral Pain Syndrome; Quadriceps Tendinitis

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Musculoskeletal Tests, Shoulder

These musculoskeletal tests are used to diagnose common injuries around the shoulder girdle. The glenohumeral joint is the most mobile joint in the body, but the large, multidirectional range of motion is a trade-off for joint stability. Lack of stability makes the shoulder more susceptible to a large spectrum of injuries, especially with overhead sports such as baseball, volleyball, swimming, and weight lifting. The shoulder girdle is important because it not only serves as the connecting joint between the arm and the axial skeleton but also serves as the base of support for movements occurring at the elbow, wrist, and hand.

Taking a thorough history is as important as the physical exam itself. The clinician should establish the patient's hand dominance and his or her occupation and recreational activities. It is important to establish the patient's chief complaint, which may include pain, instability, weakness, or loss of range of motion. Complaints of numbness and tingling may be associated with neurovascular disorders, stiffness suggests adhesive capsulitis and/or arthritis, and crepitus may indicate a bursa, osteoarthritis, or rotator cuff pathology. Patients should be able to establish a time line for when the injury occurred and what event or mechanism, if any, led to the injury or onset of symptoms. For patients reporting a dislocation, the clinician should ask what position the arm was in at the time of the dislocation and the frequency of dislocations or subluxations. Finally, it is important to establish what type of activities of daily living the patient can and cannot perform. Such activities include getting dressed, lifting an object overhead, sleeping on the shoulder, brushing the teeth, combing the hair, putting on shoes, or carrying or lifting objects such as groceries.

Examination of the Shoulder

To inspect the shoulder, the athlete must be gowned appropriately. Ideally, females should be dressed in a sports bra and shorts. A gown can be used so long as it can be opened to see the back and shoulder.

Posture

The patient's posture should be assessed from multiple positions. Much of what people do on a daily basis can affect their posture and ultimately lead to injury if abnormal mechanics are adopted. When examining a patient from the side, determine if he or she has a forward head position. Ideally, the ears should be in line with middle of the shoulder. Next, assess the position of the patient's shoulders. A high percentage of people will have their shoulders rolled forward. This is commonly an adaptation in individuals who sit at a desk or work on a computer for extended periods of time, but it can also occur from poor posture or muscular imbalances. From the front and back, examine the patient's muscular development. Typically, the height of the dominant shoulder is lower than that of the nondominant shoulder. Inspect the patient for scars, atrophy, swelling, ecchymosis, erythema, rashes, deformity, and scapula positioning. Clavicle deformity may suggest a fracture, whereas a step-off deformity at the acromioclavicular joint may indicate a shoulder "separation."

After assessing the patient's posture when seated, it is important to observe his or her posture during motion. When the patient actively abducts the arms above the head, note any jerky motions that occur at the scapulothoracic region. Ideally, the two sides should be a mirror image of one another. The glenohumeral and scapulothoracic joints should move at a 2:1 ratio during shoulder abduction. It is also important to assess the positioning of the scapula during this movement. Movement of the scapula should be symmetrical when compared bilaterally. Any "winging" or lifting off of the medial border of the scapular shoulder should be noted (see the first image). This can also be assessed by asking the patient to perform a wall push-up or repetitive shoulder flexion. Winging of the scapula may indicate atrophy of the serratus anterior due to disuse or an injury of the long thoracic nerve. The majority of abnormal winging that is seen in athletes, known as *scapular dyskinesis*, is secondary to inhibited function of the scapular stabilizers, usually due to pain from other areas in the shoulder.

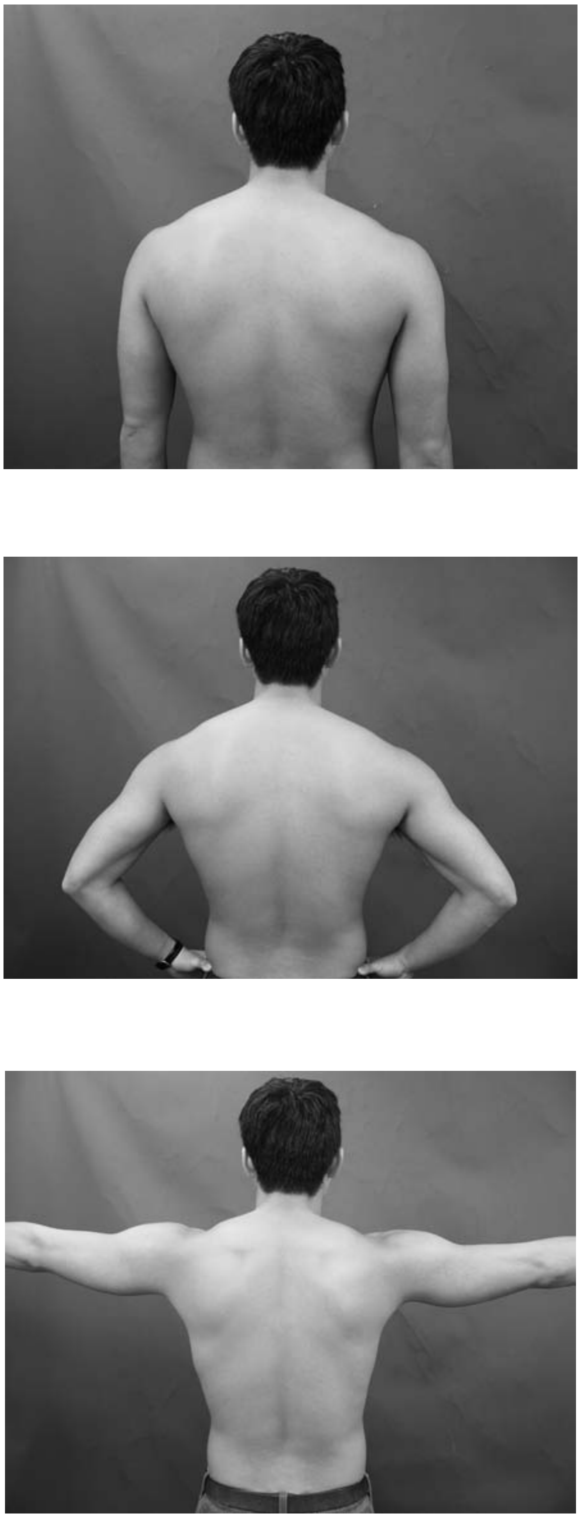
Palpation

Several important bony and soft tissue structures need to be palpated during the physical exam (see images right column, p. 943). The bony structures

Winging scapula

Source: University of California, San Francisco, Sports Medicine.

should include the sternoclavicular joint, the clavicle, the acromioclavicular joint, the coracoid process, the borders of the scapula, and the greater and lesser tuberosities of the humerus. Soft tissue landmarks include the subacromial bursae, the supraclavicular fossa, the long head of the biceps tendon, the trapezius, and other associated muscles and tendons. Starting at the sternoclavicular joint, slowly palpate the joint, and move laterally along the clavicle. Compare the "S" shape and contours of the clavicle bilaterally. Next, assess the acromioclavicular joint located at the distal end of the clavicle, where it meets the acromion process. A step-off deformity may be present if the individual has suffered an acromioclavicular sprain (separated shoulder). The coracoid process can be palpated inferior to the clavicle and medial to the long head of the biceps tendon. For palpation of the scapula, the superior angle of the scapula should be adjacent to the second rib, the spine of the scapula should be adjacent to the spinous process



Scapular function

Source: University of California, San Francisco, Sports Medicine.

of the third thoracic vertebra (T3), and the inferior border should correspond to the seven spinous processes of the thoracic vertebra (T7).

For assessment of proper scapula function, Kibler has developed a measurement test in which the examiner measures the distance from the medial border of the scapula to the spinous process of the seventh thoracic vertebra (T7). The measurement should be performed with the arm at the patient's side, hands on the hips, and arms abducted to 90° and compared bilaterally. Differences seen in these measurements may be suggestive of scapular dyskinesis (sick scapula).

In addition, the axilla should be evaluated. The anterior border of the axilla comprises the pectoralis major, the medial border being the thorax, the posterior border being the latissimus dorsi, and the lateral border being the bicep and tricep. The axilla should be assessed for masses and enlarged lymph nodes.

Range of Motion

Active range of motion performed by the athlete is typically assessed first and can be affected by pain and motor function. The patient can be either

Shoulder abduction

Source: University of California, San Francisco, Sports Medicine.

Shoulder external rotation

Source: University of California, San Francisco, Sports Medicine.

Shoulder flexion

Source: University of California, San Francisco, Sports Medicine.

seated or standing. The movements to be assessed include forward flexion, extension, internal/external rotation, and abduction/adduction. Passive range of motion is performed by the clinician with the patient seated or supine in the same planes noted

Shoulder internal rotation

Source: University of California, San Francisco, Sports Medicine.

before and is used to isolate motion for accurate evaluation of soft tissue.

Normal motion for forward flexion is 0° to 170°–180°, and extension is 60°. To accurately measure internal and external rotation, the arm should be abducted to 90°. Normal internal rotation is 90°, and external rotation is 60° to 70°. The values can vary greatly in overhead athletes such as baseball or softball players. Adduction assessment is limited due to the trunk, but typically, 30° is normal. Abduction motion is from 0° to 180°.

Apley Scratch Test

The Apley scratch test is a general test that examines the patient's active internal rotation range of motion of the shoulder.

Description of the Maneuver. The examiner stands behind the patient and instructs the patient to reach as far as possible behind the back in internal rotation and behind the neck in adduction and external rotation. Typically, the examiner can make a general assessment of the patient's ability to touch his or her fingertips. For a more formal measurement, the level of the spinous process that can be reached is documented, or the distance between the fingertips is measured. This test should be conducted bilaterally to compare differences in motion.

Positive Findings. Any bilateral differences noted in the measurements.

Apley scratch test

Source: University of California, San Francisco, Sports Medicine.

How Good Is the Test? Despite this test being widely used for assessing shoulder motion, no studies have examined the sensitivity or specificity of this test.

Rotator Cuff Strength Testing

Empty Can Test (Supraspinatus)

First described by Jobe, the empty can test is used to evaluate the strength and integrity of the supraspinatus muscle and tendon.

Description of the Maneuver. For the empty can test, the shoulder is abducted to 90° and horizontally adducted forward 30° with the thumbs pointing down toward the floor, as if pouring out something from a can. The patient is asked to maintain this position while the examiner applies downward resistance to the patient's forearm. A variation of

Empty can test

Source: University of California, San Francisco, Sports Medicine.

External rotation test

Source: University of California, San Francisco, Sports Medicine.

this test can be done at 30° abduction instead of 90°, where the supraspinatus should function in relative isolation.

Positive Findings. A positive test shows decreased strength or pain on resisted testing.

How Good Is the Test? A review of the literature indicates that the empty can test has moderate sensitivity and moderate to high specificity for detecting supraspinatus lesions and tendinitis. For supraspinatus tears, it has low sensitivity and high specificity.

External Rotation Test (Infraspinatus and Teres Minor)

The external rotation test examines the strength of the infraspinatus and teres minor.

Description of the Maneuver. With the patient's arms at his or her side, externally rotated 45° and elbow flexed to 90°, the examiner applies an internal rotation movement to assess the strength of the external rotators.

Positive Findings. Decreased strength or pain on resisted testing indicates a positive test. Significant weakness of the infraspinatus may be indicative of suprascapular nerve palsy, where the infraspinatus becomes denervated. This can be due to trauma, a ganglion cyst, or illness.

How Good Is the Test? A review of the literature reveals that the external rotation test demonstrates low sensitivity and moderate specificity for detecting tendinitis and bursitis, while it has moderate sensitivity and high specificity for detecting partial to complete rotator cuff tears.

Lift-Off Test (Lower Subscapularis)

The lift-off test, described by Gerber and Krushell, evaluates the muscular strength of the subscapularis.

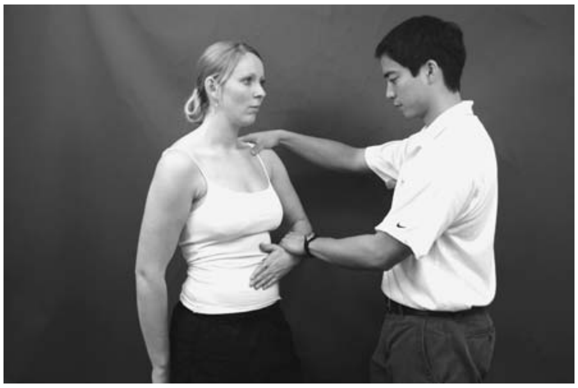
Description of the Maneuver. With the patient seated or standing, the arm of the patient is internally rotated behind his or her back. The patient is asked to lift the back of the hand off the lower back. If the patient is able to the complete this task, the clinician then applies resistance to the palm to assess the strength of the subscapularis.

Positive Findings. Inability of the athlete to lift the dorsum of the hand off the back indicates a positive test.

How Good Is the Test? The literature indicates that the lift-off test has moderate sensitivity and high specificity for detecting subscapularis lesions, such as tendinitis and tears.

Lift-off test

Source: University of California, San Francisco, Sports Medicine.



Belly press test

Source: University of California, San Francisco, Sports Medicine.

Belly Press Test (Upper Subscapularis)

The belly press test examines the strength of the subscapularis.

Description of the Maneuver. The patient places his or her hand on his or her belly. The clinician attempts to lift the hand off the abdomen while the patient resists.

Positive Findings. The athlete complains of decreased strength or inability to hold the hand against the abdomen.

How Good Is the Test? There are no studies examining the sensitivity or specificity of this test.

Impingement/Rotator Cuff Special Tests

Impingement can occur when the soft tissue structures (rotator cuff, bursa, biceps, and tendon) that lie within the subacromial space become compromised or pinched between the acromion and the greater tuberosity, typically with overhead motions and internal rotation maneuvers.

Neer Impingement Test

The Neer impingement test assesses the presence of impingement of the rotator cuff, primarily the supraspinatus, as it passes under the subacromial arch during forward flexion. Dr. Charles Neer first described this test in 1972.

Description of the Maneuver. With the patient standing, the clinician stabilizes the scapula with one hand while applying passive force for flexion of the arm.

Positive Findings. Pain in the anterior shoulder or reproduction of the patient's symptoms signifies a positive test.

How Good Is the Test? The literature suggests that this test has high sensitivity and moderate specificity.

Neer impingement test

Source: University of California, San Francisco, Sports Medicine.

In addition, it has moderate positive predictive value and moderate negative predictive value.

Hawkins Test

The Hawkins test, described by Drs. Hawkins and Schutte, is used to evaluate impingement of the rotator cuff and subacromial bursa.

Description of the Maneuver. The patient is seated or standing with the arm forward flexed to 90° and the elbow bent at 90°. The clinician stabilizes the top of the shoulder while internally rotating the arm at the forearm.

Positive Findings. Pain in the anterior shoulder or reproduction of the patient's symptoms with the test indicates a positive test.

How Good Is the Test? Several studies examining the efficacy of this test demonstrate moderate to high sensitivity and low to moderate specificity. In addition, the test has shown moderate positive predictive value and moderate negative predictive value.

Special Tips for Improving Accuracy. The clinician can stand at the side of the athlete with one hand on top of the shoulder, keeping the patient from elevating the shoulder. The other hand is positioned close to the elbow with the thumb down, making it more comfortable for the examiner to internally rotate the arm. The test should not be done with the arm abducted.

Drop Arm Test

The drop arm test examines for rotator cuff tears, most specifically in the supraspinatus.

Description of the Maneuver. With the patient standing, the clinician abducts the arm to 90° and instructs the patient to slowly lower his or her arm to the side.

Positive Findings. Severe pain or an inability to slowly lower the arm to the patient's side is a positive finding. The arm typically drops suddenly at approximately 90°.

How Good Is the Test? A review of the literature indicates that the drop arm test has low sensitivity and high specificity in identifying both tendinitis and rotator cuff tears.

Patte "Dropping" Test

The Patte test, developed by Patte in 1995, evaluates the integrity of the infraspinatus or teres minor.

Description of the Maneuver. With the arm flexed to 90° in the plane of the scapula and the elbow

Hawkins test

Source: University of California, San Francisco, Sports Medicine.

Patte test

Source: University of California, San Francisco, Sports Medicine.

flexed to 90°, the patient is instructed to externally rotate the arm while the clinician applies resistance to the forearm.

Positive Findings. Pain, decreased strength, or inability to externally rotate the forearm when compared bilaterally indicates a positive test.

How Good Is the Test? The Patte test demonstrates moderate sensitivity and moderate to high specificity in detecting infraspinatus lesions, tendinitis, and tears. In addition, the test has also shown high positive predictive value and moderate negative predictive value for detecting these pathologies.

Yocum Test

The Yocum test assesses impingement of the rotator cuff.

Description of the Maneuver. The patient is instructed to place the hand on the opposite shoulder and then raise the elbow while keeping the hand on the shoulder.

Positive Findings. A positive test is pain in the anterior shoulder or reproduction of symptoms.

How Good Is the Test? The literature has shown the Yocum test to possess moderate sensitivity and moderate specificity when performed in combination with the Hawkins and the Neer test.

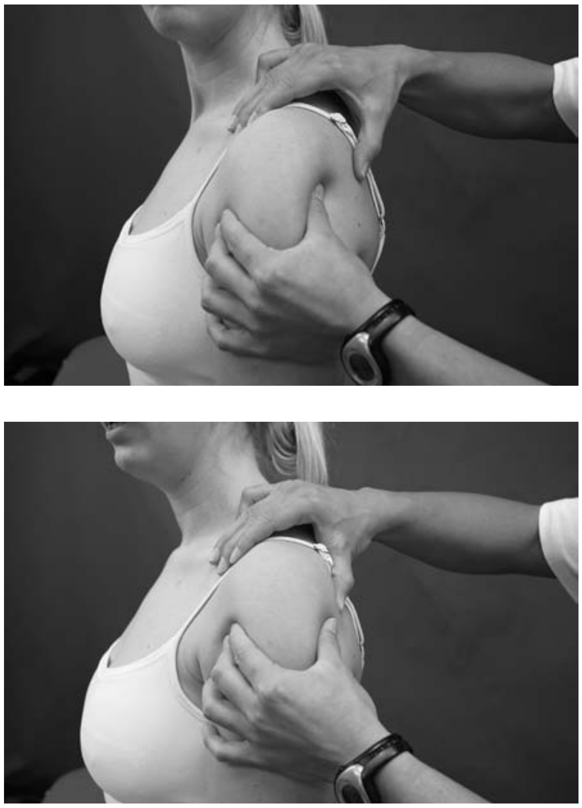
Special Tests to Examine Shoulder Instability

Load and Shift Test

The load and shift test examines the integrity of shoulder stability in the anterior and posterior directions.

Yocum test

Source: University of California, San Francisco, Sports Medicine.



Load and shift test

Source: University of California, San Francisco, Sports Medicine.

Description of the Maneuver. The patient is seated or supine with his or her arm relaxed and resting at the side. The clinician grasps the head of the humerus between his or her thumb and fingers and applies anterior and posterior glide from the resting position.

Positive Findings. A positive sign is excessive gliding of the humeral head. The degree of stability can be graded: Grade 0 stability means no gliding from the center of the glenoid, Grade 1 equals translation to the glenoid rim, Grade 2 stability leads to translation of the head over the glenoid rim but no locking, and Grade 3 stability results in the head of the humerus locking over the glenoid rim.

How Good Is the Test? Research has shown high sensitivity and specificity for the load and shift, as well as high positive predictive value in diagnosing Bankart lesions. However, there is no good correlation between examiners because the measurement of translation is somewhat subjective.

Apprehension Test

The apprehension test, described by Row and Zarin, examines for anterior instability of the shoulder.

Description of the Maneuver. The patient is supine on the table, and his or her arm is abducted with the elbow flexed to 90°. The clinician gently rotates the arm externally. The test is often performed in conjunction with the relocation and surprise tests.

Positive Findings. The patient may complain of pain or be apprehensive that his or her arm may dislocate as the arm is externally rotated.

How Good Is the Test? The literature indicates that the apprehension test has moderate sensitivity and moderate specificity in detecting labral pathology that often leads to instability of the joint.

Relocation Test

The relocation test, described by Jobe, is used in conjunction with the apprehension test to distinguish between anterior instability and primary impingement of the shoulder.

Description of the Maneuver. The apprehension test is performed first, and when the patient becomes apprehensive or complains of pain, the clinician applies a posterior force to the humeral head.

Apprehension test

Source: University of California, San Francisco, Sports Medicine.

Relocation test

Source: University of California, San Francisco, Sports Medicine.

Positive Findings. The relocation test is positive if the symptoms of apprehension reduce or if the clinician is able to externally rotate the shoulder further without increase in pain or apprehension. If the symptoms persist following the posterior-directed force, the pain is associated with primary impingement and not anterior shoulder instability.

How Good Is the Test? A review of the research suggests that the relocation test has moderate sensitivity and moderate to high specificity in detecting labral pathology.

Sulcus Sign

The sulcus sign tests for inferior instability caused by laxity of the inferior glenohumeral ligament complex.

Description of the Maneuver. The patient is seated with his or her arm resting at the side. The clinician grasps the upper arm and applies a distal force to the arm.

Positive Findings. A positive sign is increased inferior movement of the humeral head or the visible development of a sulcus at the glenohumeral joint. A positive test often suggests that the athlete has multidirectional instability if there are other signs of join instability.

Sulcus sign

Source: University of California, San Francisco, Sports Medicine.

How Good Is the Test? So far no studies have examined the validity of the sulcus sign as it pertains to inferior instability.

Labral Special Tests

Active Compression/O'Brien Test

The active compression test, developed by O'Brien and Pagnani, assesses the integrity of the glenoid labrum and the acromioclavicular (AC) joint.

O'Brien test

Source: University of California, San Francisco, Sports Medicine.

Description of the Maneuver. With the patient seated or standing, the patient is instructed to raise his or her arm into 90° of forward flexion with the elbow extended and then adduct the arm to 10° to 15°. The patient internally rotates the arm and points the thumb down to the ground. The clinician applies a downward force to the arm. Afterward, the patient is instructed to externally rotate the arm and point the thumb toward the ceiling, and the clinician again applies a downward force.

Positive Findings. Positive findings for labral pathology occur when the first test reproduces pain while the second test decreases or eliminates pain. The pain associated with labral tears is described deep in the shoulder. Pain situated over the AC joint is associated with AC joint pathology, such as osteoarthritis or a shoulder separation, rather than labral pathology. Pain in the AC joint is usually equal with the palm down or the palm up.

How Good Is the Test? Several studies have reported validity data regarding the active compression test. A review of the literature has shown the test to have moderate to high sensitivity and low to high specificity for detecting labral tears and AC joint pathology and high positive predictive value and high negative predictive value.

Crank Test

Liu and Henry first described the crank test to assist clinicians in determining the presence of a labral tear.

Crank test

Source: University of California, San Francisco, Sports Medicine.

Description of the Maneuver. The patient is seated or supine with his or her arm flexed to 60° in the scapular plane. The clinician applies a load across the axis of the humerus while the other hand rotates the arm.

Positive Findings. Pain during external rotation or reproduction of symptoms, which usually consist of pain or clicking, is a positive sign.

How Good Is the Test? The literature suggests the crank test to have high sensitivity and high specificity with high positive predictive value and high negative predictive value.

Compression-Rotation Test

The compression-rotation test checks for the integrity of the labrum.

Description of the Maneuver. With the patient supine, the arm is abducted to 90° with the elbow flexed to 90°. The clinician applies an axial force to the humerus and attempts to push the humeral head against the torn part of the labrum.

Positive Findings. Pain or catching of the labrum signifies a positive test.

How Good Is the Test? The validity examination has shown the compression-rotation test to have high sensitivity and low specificity in detecting labral pathology.

Special Tests to Examine Thoracic Outlet Syndrome

A less common diagnosis for shoulder and diffuse upper extremity pain is thoracic outlet syndrome. The symptoms include weakness, pain, and numbness of the upper extremity and pain that radiates from the shoulder into the hand and fingers. The symptoms occur when the neurovascular structures around the neck and clavicle are compromised when the arm is in an overhead position.

Adson Maneuver

Adson and Coffey first described this maneuver to assist clinicians in examining possible compression

Adson maneuver

Source: University of California, San Francisco, Sports Medicine.

of the subclavian artery between the scalene anticus and the cervical rib.

Description of the Maneuver. In a seated position, the patient extends the neck and turns the head toward the shoulder being tested while that shoulder is slightly abducted and extended. The patient inhales while the examiner palpates the ipsilateral radial pulse.

Positive Findings. Diminution or elimination of the pulse and reproduction of the paresthesias indicate a positive test, provided that they do not occur on the asymptomatic, contralateral side.

How Good Is the Test? Studies have documented the Adson maneuver to have poor to good specificity and good sensitivity.

Wright Hyperabduction Test

Wright originally described this maneuver in 1945 and suggested that the neurovascular symptoms in the upper extremity were attributed to compression by the pectoralis minor.

Description of the Maneuver. With the patient seated, the clinician progressively hyperabducts and externally rotates the patient's arm while assessing for ipsilateral radial pulse.

Positive Findings. Diminution or elimination of the radial pulse and reproduction of the paresthesias is indicative of a positive test.

Wright hyperabduction test

Source: University of California, San Francisco, Sports Medicine.

How Good Is the Test? No studies have examined the validity of the Wright hyperabduction test as it pertains to thoracic outlet syndrome.

Roos Stress Test

This test was first described by Roos to assess entrapment of the neurovascular bundle in the upper extremity.

Roos stress test.

Source: University of California, San Francisco, Sports Medicine.

Description of the Maneuver. The Roos stress test is performed with the patient holding his or her shoulders in abduction and external rotation of 90° while maintaining elbow flexion at 90°. The patient is instructed to repeatedly open and close his or her hands for 3 minutes.

Positive Findings. Reproduction of these symptoms or a sensation of heaviness and fatigue is consistent with a positive finding and a diagnosis of thoracic outlet syndrome.

How Good Is the Test? No studies have examined the validity of the Roos stress test as it pertains to thoracic outlet syndrome.

Derek Hirai and Anthony Luke

See also Acromioclavicular (AC) Joint, Separation of; Clavicle (Collarbone) Fracture; Glenoid Labrum Tear; Rotator Cuff Tendinopathy; Shoulder Bursitis; Shoulder Dislocation; Shoulder Impingement Syndrome; Shoulder Injuries; Shoulder Instability; Shoulder Subluxation; Sternoclavicular (SC) Joint, Separation of; Superior Labrum From Anterior to Posterior (SLAP) Lesions

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Musculoskeletal Tests, Spine

These musculoskeletal tests are used to diagnose common injuries around the spine. Back pain ranks second only to the common cold as a symptomatic reason to visit the doctor's office. Approximately 70% of adults have one or several significant bouts of low back pain at some time in their lives. Fortunately, most causes of back pain respond to conservative treatment measures early on. However, following recurrent episodes of back pain, the natural history is typically progressive degenerative change as one ages.

The spine plays a central role in achieving the maneuvers involved in sports. The axial skeleton allows the peripheral limbs to perform functional sports movements while the spine transmits energy and forces. Sports that use the upper extremities often involve twisting motions, which lead to more athletic-related injuries in the back than sports that use the lower extremities predominantly. Because the back functions integrally with the pelvis and hips, patients may complain of pain in the spine or pelvic area, with problems affecting function in the other sites, especially the hips and lower extremities. The clinician should evaluate the spine as well as the hip during the examination.

Lumbar Spine

Common injuries include muscle and ligament strains, degenerative disk disease (i.e., herniated disk), scoliosis (curved spine), and osteoarthritis. The physical exam of the spine and associated systems is important to determine that back pain is coming from the spine and not from a systemic disease such as cancer or an internal organ pain referring to the back.

The most common cause of back pain in the adult population involves *degenerative disks leading to disk herniation.* The most common areas of disk herniation are at the lowest part of the lumbar spine, L4-L5 or L5-S1 level, as well as the lower part of the neck. If the disk herniation in the lower back is large, it can cause nerve impingement, leading to radiating pain down the leg, known as *sciatica.* Sciatica is typically a pain that radiates from the spine in typical nerve distribution, affecting the sciatic nerve that runs down the back of the leg to the foot. When the sciatic nerve is compressed, usually by a lumbar disk herniation at the L4-L5 or L5-S1 level, the patient experiences pain, weakness, and numbness in the leg, often below the level of the knee. The pain is usually reproduced with back flexion.

Cauda equina, seen in 1% to 2% of lumbar disk herniations, is a surgical emergency. A large disk herniation can compromise the spinal cord and put pressure on it. The most consistent finding is urinary retention, though numbness around the buttocks and anus, known as saddle anesthesia, is a danger sign. Osteoarthritis can also cause problems in the lower back, especially if there is narrowing of the spinal canal due to the arthritis changes, referred to as *spinal stenosis*. Patients with spinal stenosis may report neurogenic claudication, complaining of leg pain, weakness, and gait unsteadiness after walking. Symptoms of spinal stenosis typically worsen with standing and back extension and may improve with sitting and flexion.

Examination of the Spine

The back exam is more easily performed using an approach based on the position of the patient, specifically standing, sitting, supine, and prone, instead of using a LOOK (inspection), FEEL (palpation), MOVE (range of motion), and special tests that can be used to examine many of the peripheral joints. By combining the exam and positioning of the patient, elements of the inspection, palpation, movement, and special tests are involved, making the exam more efficient.

Standing

To inspect the back, the athlete must be gowned appropriately, in shorts without socks and shoes. Females should be dressed in a sports bra and shorts. A gown may be used as long as it can be opened to see the back.

Skin and Muscles

The musculature and skin can be quickly examined by exposing the back. The examiner can check for muscle spasm, which is often more obvious when standing and moving the spine. Any atrophy of the muscles should be noted since it may suggest a long-standing problem. Skin lesions are documented, especially any irregular spots and rashes.

Posture

Posture is an important factor in back conditions. The athlete's alignment can be assessed from the side. Using a plumbline, general landmarks that should line up include the earlobe, acromioclavicular joint, lateral hip (greater trochanter), and outside ankle (lateral malleolus). Excessive curvature at the upper back is referred to as *kyphosis*. From the back, the shoulders, pelvis, and skin folds at the buttocks and behind the knees can be grossly checked to make sure they are at similar levels. Asymmetries can be examined more closely to see what the underlying cause is. Postural abnormalities that are frequently seen include head forward posture, rolled forward shoulder posture, and hyperextension at the lower back (*hyperlordosis*).

Scoliosis

Scoliosis refers to side-to-side curvature of the spine greater than 10°. The curve is best seen when the athlete bends forward. Because there are rotational changes with a lateral curve, when the athlete bends forward, there is a hump that is higher on the side the curve it is pointing toward. A curve at the upper spine toward the right is the most common type of scoliosis. When there is one curve, a second corrective curve can occur. Less commonly, there can be a triple or quadruple curve.

Kyphosis

Source: University of California, San Francisco, Sports Medicine.

Scoliosis

Source: University of California, San Francisco, Sports Medicine.

Walking/Gait

The athlete's mechanics should be observed while walking, looking for limited movement at the spine, asymmetries of gait, and signs of muscle weakness. Specifically, difficulty walking on one's heels suggests an L5 nerve root problem, while difficulty walking on one's toes suggests S1 nerve root weakness.

Peripheral Joint–Scanning Exam

If the athlete has abnormal biomechanics and signs of asymmetry, it is obviously important to rule out any pathology in the extremities that may be influencing the spine. A functional maneuver, such as asking the athlete to squat and take a few steps in the squatted position (duck walk), can quickly screen for problems at the hips, knees, ankles, and feet.

Special Tests (Standing)

Schober Test

The Schober test checks for flexion range of motion at the lumbar spine. When it is reduced, it may suggest conditions that cause stiffness at the lumbar spine.

Description of the Maneuver. With the examiner standing behind the patient, the top of the tailbone (sacrum) is palpated, and a mark is made at 10 centimeters (cm) higher from this point. The athlete then bends as far forward as possible without bending at the knees, and the distance is measured.

Positive Findings. The increased distance between the top of the tailbone should measure more than 14 cm. A positive test means that the distance in flexion is less than 14 cm, suggesting limited movement.

How Good Is the Test? The reproducibility of the test is moderate.

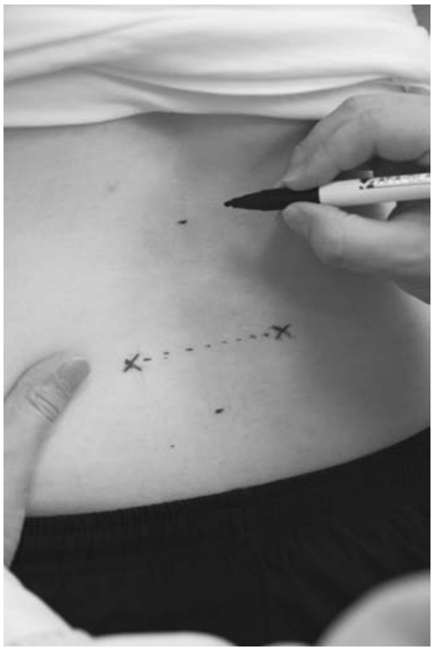
Modified Schober Test

The modified Schober test checks for flexion range of motion at the lumbar spine. When it is reduced, it may suggest conditions that cause stiffness at the lumbar spine.

Description of the Maneuver. From behind the standing patient, the posterior superior iliac spines of the pelvis are palpated (there are dimples typically visible in this area), and a line is drawn across. A mark is made 10 cm above the line, and another mark is made at 5 cm higher from this point. The athlete then bends as far forward as possible without bending at the knees, and the distance between the two marks is measured.

Positive Findings. The distance between the marks should normally increase 5 cm or more with flexion (e.g., the distance between the marks increased from 15 cm to more than 20 cm in 90% of the population.

How Good Is the Test? The sensitivity of the modified Schober test is low, the specificity is high, and the reproducibility of the test is good.



Modified Schober test

Source: University of California, San Francisco, Sports Medicine.

Trendelenburg Test

The Trendelenburg test examines for *weakness or instability of the hip abductors,* primarily the gluteus medius.

Trendelenburg test (negative)

Source: University of California, San Francisco, Sports Medicine.

Trendelenburg test (positive)

Source: University of California, San Francisco, Sports Medicine.

Description of the Maneuver. The patient balances first on one leg, raising the nonstanding knee toward the chest. The examiner can stand behind the athlete and observe for any misalignment and dropping of the pelvis or buttock on the nonstance side.

Positive Findings. If the pelvis on the side of the nonstance leg rises, the test is negative. If the pelvis of the nonstance leg falls, the test is positive, indicating weakness or instability of the hip abductors, primarily the gluteus medius, on the stance side.

How Good Is the Test? The Trendelenburg test has moderate to good sensitivity and specificity for detecting a tear in the gluteus medius muscle.

Gillet Test (March Test)

The Gillet test assesses for asymmetric movement around the sacroiliac (SI) joints, suggesting biomechanical dysfunctions. The test is done in a similar fashion to the Trendelenburg test.

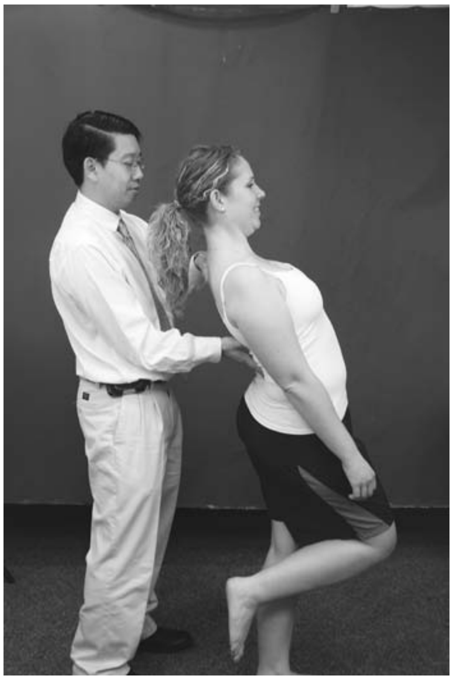
Description of the Maneuver. The examiner palpates the posterior superior iliac spine (PSIS) on one side with the thumb and the horizontal sacral spine with the other thumb while the athlete is standing. The patient then pulls the non–weight-bearing knee up toward the chest. The examiner keeps a thumb gently over the PSIS to assess the movement that occurs at the joint. Normally, the thumb and joint will move laterally and downward. Upward movement of the thumb and SI joint is abnormal. The test can also be repeated with one thumb over the ischial tuberosity and the other over the apex of the sacrum. Repeat on the other side.

Positive Findings. Normally, PSIS will drop downward and move laterally. If the PSIS moves minimally or in an upward direction, it is a positive test, suggesting SI fixation, hypomobility, or dysfunction.

How Good Is the Test? This test has poor reliability among examiners and is very subjective.

One-Leg Standing Hyperextension (Stork) Test

The one-leg standing extension test assesses for pain in the back on extension, which can be associated with pars interarticularis fractures (spondylolysis or spondylolisthesis).



One-leg standing hyperextension test

Source: University of California, San Francisco, Sports Medicine.

Description of the Maneuver. The athlete stands on one leg while extending the spine. The examiner stands behind, supporting the athlete to allow him or her to extend fully on one leg.

Positive Findings. A positive test is indicated by pain in the back, usually in the lowest lumbar vertebrae (L5 or L4), when the athlete is extended. The pain is usually on the side of the stance leg.

How Good Is the Test? This test has poor sensitivity and specificity for detecting spondylolysis.

Special Tips for Improving Accuracy. The examiner can stand directly behind the athlete and place one hand on the athlete's shoulder and the other hand with the (examiner's) arm extended on the patient's lower back. This can help unload some of the individual's weight as the athlete extends backward, allowing him or her to balance more easily.

Range of Motion

The examiner can ask the athlete to actively move to check the motion at the spine. The common directions include flexion, extension, and rotation. Passive movements, with the examiner assisting the athlete to move, are sometimes difficult to perform because of the weight of the athlete's body. If active movements are full and painfree, overpressure can be attempted with care. Avoid exacerbating suspected painful movements during the exam if possible.

Though the spine motion flexes almost 90° to 100°, the forward flexion actually occurs at both the spine and the pelvis and hips. The lumbar spine flexes approximately 40° to 60° and extends around 20° to 35°. When the spine bends forward, it is locked in flexion so that lateral bending and rotation do not occur and the back can receive axial loading. Motion can be limited by ligament tightness, pathology in the spinal elements such as osteoarthritis, or anatomical variants including scoliosis.

Lateral bending of the lumbar spine can occur when the spine is in extension, while almost no bending occurs in flexion. Lateral bending of the lumbar spine ranges from 15° to 20°. With lateral bending, the spine also rotates; for example, as the spine bends laterally to the left, it also rotates toward the right. Similarly, axial rotation can occur in the extended position with motion averaging approximately 15° to 20°. Minimal rotation occurs in full flexion.

Sitting

The athlete can now be asked to sit on the exam table. Observe how the patient gets on the table, especially if he or she has to use a step to get on the table. The neurological exam for the lower extremities can easily be performed with the patient in the sitting position. Alternatively, the neurological exam can be done with the patient supine.

Cervical spine range of motion

Source: University of California, San Francisco, Sports Medicine.

Lumbar flexion

Source: University of California, San Francisco, Sports Medicine.

Lumbar extension

Source: University of California, San Francisco, Sports Medicine.

Lateral bending

Source: University of California, San Francisco, Sports Medicine.

Lateral rotation

Source: University of California, San Francisco, Sports Medicine.

Strength Testing (Myotomes)

The examiner can check for weakness by eliciting a resisted isometric contraction for approximately 5 seconds in major muscles in the lower extremities. It is important to compare the strength bilaterally to detect subtle weaknesses. The strength

Hip flexion, L1-L2

Source: University of California, San Francisco, Sports Medicine.

Ankle dorsiflexion, L4-L5

Source: University of California, San Francisco, Sports Medicine.

Knee extension, L3

Source: University of California, San Francisco, Sports Medicine.

First toe extension, L5

Source: University of California, San Francisco, Sports Medicine.

Ankle plantarflexion, S1

Source: University of California, San Francisco, Sports Medicine.

can be graded from 1 (*no muscle activitation*) to 5 (*full strength*). The following muscle groups should be tested. The associated primary nerve roots are indicated in brackets: hip flexors (L1-L2), knee extensors or quadriceps (L3), ankle dorsiflexors (L4-L5), first toe extensor or extensor hallucis longus (L5), knee flexors or hamstrings (S1), ankle plantarflexors or calf muscles (S1), and hip extensors (S1).

Sensation (Dermatomes)

Dermatomes are areas of skin where the sensation is supplied by specific nerve roots in the spine. These dermatomes can vary subtly from person to person. The approximate distributions for common areas in the lower extremity and their nerve roots are as follows: groin (L1), thigh (L2), knee (L3), lateral shin and medial ankle (L4), first dorsal web space of the foot between the first and second toes (L5), lateral foot (S1), back of the thigh (S2), and perianal area (S3, S4, S5).

Reflexes

Using a reflex hammer, the reflexes of the lower extremity can be assessed. These are typically graded as +2 = *normal reflexes*, +3 = *hyperreflexic (increased) reflexes*, +1 = *hyporeflexic (decreased) reflexes*, and 0 = *absent reflexes*.

The knee reflex is elicited by tapping the patellar tendon over the anterior knee while the athlete is relaxed, causing contraction of the quadriceps and subsequent extension of the knee. The knee reflex tests the L3 and L4 nerve roots.

The ankle reflexes can be tested by tapping the posterior aspects of the Achilles tendon with the foot resting in the neutral position, which causes a reflex plantarflexion of the foot. The ankle reflex tests the S1 nerve root.

The Babinski reflex is elicited by quickly brushing the sole of the foot from the heel to the big toe on each side. The normal response to this maneuver is dorsiflexion of the first toe. Patients with central spinal cord or brain lesions involving the upper motor neurons may have an abnormal response such as flexion of the big toe downward. Some patients do not demonstrate any movement on either side, which is normal as long as the reflexes are symmetric on both sides.

Special Tests (Sitting)

Modified or "Indirect" Straight Leg Raise Test

The modified or "indirect" straight leg raise (SLR) is a test that puts traction and compression forces on the lower lumbar nerve roots, reproducing the mechanism of compression of the nerve root usually caused by disk herniation. This is performed in a seated position, whereas the classic SLR test is performed with the patient lying supine. Both tests should be done during the exam to check if the findings are consistent (see also Straight Leg Raise Test and Waddell Tests).

Description of the Maneuver. With the patient sitting, the examiner passively extends the knee. The examiner explains that he or she is checking the patient's ankle or the Babinski reflex, so as not to reveal what the examiner is looking for.

Positive Findings. The test is positive if pain extends from the back down the leg in a sciatic nerve distribution.

Modified straight leg raise

Source: University of California, San Francisco, Sports Medicine.

Slump test

Source: University of California, San Francisco, Sports Medicine.

Slump Test

The slump test is a neurodynamic test, placing mechanical stress, traction, or compression on neurologic tissues in the lumbar spine. This test looks for sciatica and can be performed in conjunction with the SLR test and indirect SLR test. For these tests to be positive, they must reproduce the patient's symptoms regardless of discomfort and pain.

Description of the Maneuver. The athlete sits on the table with his or her hands behind the back. The patient is asked to "slump forward" at the lumbar and thoracic spine while keeping the head in a neutral position. The examiner can apply pressure across the shoulders to maintain thoracolumbar spine flexion. The patient is then asked to fully flex the neck, "chin to chest." The examiner applies overpressure to the cervical spine to maintain cervicothoracolumbar flexion. The examiner then holds the foot in dorsiflexion, and the patient is asked to actively straighten his or her knee, or the examiner passively extends it. The test is then repeated with the other leg.

Positive Findings. A positive test is if the patient's symptoms are reproduced at any stage, with shooting pain from increased tension in the spinal cord and sciatic nerve. The patient's symptoms often decrease with neck extension. The athlete may become apprehensive about being placed in the slump test position and may lean backward to avoid further flexion of the spine.

How Good Is the Test? The reliability of this test between examiners is high.

Special Tips for Improving Accuracy. If the patient is unable to fully extend the knee because of pain, the patient is allowed to actively extend the neck for relief, allowing further knee extension.

Supine Tests (Hip)

The hip is examined while the patient is in the supine position. To screen for intraarticular hip pathology, the range of motion in the hip can be checked by moving the hip in full internal and external rotation. If the patient is suspected to have significant trauma or discomfort in the hip, the leg can be "logrolled" in extension to perform gentle internal and external rotation at the hip.

Straight Leg Raise Test or Lasegue Test

The SLR test is the classic test for identifying symptoms of sciatica. The test puts traction and compression forces on the lower lumbar nerve roots, reproducing the mechanism of compression of the nerve root usually caused by disk herniation.

Description of the Maneuver. The examiner flexes the patient's hip while maintaining knee extension until the end of the range of motion is reached passively or the patient has painful symptoms. Most individuals can be flexed at the hip to 80° or 90° unless they have symptoms of pain or tight hamstrings. Very flexible individuals, such as dancers, may flex more than 90°.

Straight leg raise

Source: University of California, San Francisco, Sports Medicine.

Positive Findings. The SLR test is positive if the patient complains of pain extending from the back down the leg in the sciatic nerve distribution (primarily L4, L5, or S1-S2 sciatic nerve roots). A positive test should occur when the leg is flexed between 30° and 70° while the sciatic nerve root stretches from 30° to 70°.

How Good Is the Test? Sensitivity of sciatica for herniated disk is high, with moderate specificity. The reliability is high if the test is negative; however, it is only moderate if the test is positive. The maneuver may cause mechanical loading on the lumbar spine, which can be a positive sign for low back pain but not the classic positive sign for sciatica.

Special Tips for Improving Accuracy. To confirm symptoms based on stretching of the sciatic nerve, the examiner can drop the leg back down approximately 10° until the symptoms disappear. The examiner can then passively dorsiflex the foot, which will provoke the sciatica symptoms in a similar fashion.

If the patient shows symptoms of pain between 0° and 30° of flexion at the hip or at greater than 70°, suspect that it originates from the sacroiliac joints, the facet joints, or a tight hamstring.

Crossed Leg/Straight Leg Raise Test

The crossed leg/straight leg raise test is another neurodynamic test that is usually indicative of a large intervertebral disk protrusion.

Description of the Maneuver. The examiner flexes the hip while maintaining knee extension until the end of the range of motion is reached passively or the patient has symptoms of pain. The test is similar to the SLR test except that pain is noticed in the nonlifted leg.

Positive Findings. A positive test reproduces the patient's sciatic pain in the nonlifted leg, which suggests that the disk herniation is large and is compressing the opposite nerve root.

How Good Is the Test? The test has low to moderate sensitivity but high specificity.

Spine palpation

Source: University of California, San Francisco, Sports Medicine.

Prone (Lying Face Down)

Palpation of the Spine

Palpation of the spine is easiest in the prone position. With the athlete face down on the exam table, the examiner can palpate many of the underlying muscles and structures of the spine. The spinous processes, facet joints, and transverse processes may be palpable if the individual does not have much overlying soft tissues. The examiner can identify the levels of vertebral point tenderness. General percussion can identify other areas of tenderness, including kidney pain near the lower areas of the rib cage posteriorly. Spasms involving the paraspinal muscles can be noted. Other bony landmarks including the ischial tuberosity and greater trochanter can be palpated.

Femoral Nerve Traction Test

The femoral nerve traction test is a neurodynamic test that stretches the femoral nerve and its corresponding nerve roots (L2, L3, L4).

Description of the Maneuver. The patient lies face down with the knee bent. While holding the foot with one or two hands, the examiner lifts the leg toward the ceiling, extending the hip to 15°. A variation of the test can be performed in a similar fashion with the athlete lying on his or her side with the back straight and neck slightly flexed. The examiner can extend the hip to 15° with the knee extended. The examiner then flexes the knee.

Positive Findings. Pain radiating down the anterior thigh is a positive test for the femoral nerve stretch test.

Rectal Exam

If there is concern regarding serious compression of the spinal cord, a physician should perform a rectal exam. Early symptoms suggesting cauda equina include saddle area or perianal sensory changes or paresthesias. The individual may also have lower extremity neurological weakness or deficits, or incontinence symptoms. Cauda equina syndrome is a surgical emergency, and the athlete should be treated immediately.

Special Tests of Malingering

Malingering refers to a behavior where the patient exaggerates or creates fake symptoms, usually for secondary gain purposes, such as financial gain, drugs, or avoidance of work/school. Back pain is a very common complaint used by individuals who are malingering.

Femoral nerve stretch test

Source: University of California, San Francisco, Sports Medicine.

Waddell Tests

Waddell tests are a series of maneuvers used to differentiate between physical and nonphysical back pain. These maneuvers do not typically affect the lumbar spine sufficiently to produce mechanical load leading to exacerbation of back pain symptoms. If the patient complains of significant back pain, these would be inconsistent with the usual causes of mechanical back pain. The examiner needs to consider other medical or nonorganic causes of back pain or secondary gain issues for the patient.

Description of the Maneuver. There are six maneuvers for the Waddell signs. Each of the following can be tested to see how the patient reacts:

1. Superficial skin tenderness to a light pinch over a wide area of the lumbar spine
2. Deep tenderness over a wide area, often extending to the thoracic spine, sacrum, and/or pelvis
3. Low back pain on axial loading of the spine in standing
4. A positive SLR test in the supine position but not with the indirect SLR (The examiner can test the patient when seated and extend the knee to test the Babinski reflex, so that the patient does not know what the examiner is looking for)
5. Abnormal or inconsistent neurological (motor and/or sensory) patterns
6. Overreaction to maneuvers in the regular back exam

Positive Findings. Each test counts +1 if positive or 0 if negative. Positive findings of +3 or more should be investigated for nonorganic causes.

Hoover Test

The Hoover test assesses for inconsistent effort during the examination when asking the patient to actively flex his or her hip. This test can be performed to check whether the patient is putting in genuine effort during strength testing of the hip flexors. When flexing the hip on one side, the individual must extend the hip actively on the opposite side, stabilizing the pelvis.

Hoover test

Source: University of California, San Francisco, Sports Medicine.

Description of the Maneuver. With the patient lying supine, the examiner places his or her hands under each heel (calcaneus). The patient is asked to lift one leg off the table keeping the knee straight. The test is repeated on the opposite leg.

Positive Findings. If the patient does not lift the leg or the examiner does not feel pressure under the opposite hand, the patient is probably not trying. If the lifted limb is weaker, normally the pressure under the normal heel increases because of the increased effort to lift the weak leg.

Anthony Luke

See also Musculoskeletal Tests, Hip

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Narcotic Analgesics

Narcotic analgesics are strong pain relievers. As such, they are strictly controlled substances, and a prescription is needed to obtain or possess them. When used appropriately, athletes may take narcotics when recovering from serious injuries or surgery. However, narcotics have also been exploited by athletes, who may abuse them to train harder and longer with less perceived effort. Athletes have also used narcotics to mask the pain of nagging injuries in order to avoid taking time off from training or missing competitions. Unfortunately, this type of use can hinder recovery, create an opportunity for more serious injury, and theoretically lead to a cycle of narcotic dependence.

Opium, the original narcotic analgesic, is extracted from a species of the poppy flower and has been used for centuries. Opium and its derivative heroin currently do not have medicinal applications. Heroin is extremely addictive in all forms. People who abuse heroin may smoke, snort, or inject it.

Morphine is another derivative of opium (i.e., an opioid) that has been modified and refined for appropriate medical use. Today, there are many natural, semisynthetic, and synthetic derivatives of morphine that are used as injections, pills, liquids, and even slow-release transdermal patches. These preparations vary in their onset, duration, and safety profile. There are many options for effective pain control, but the potential for tolerance, dependence, and abuse always exists with narcotics.

Narcotic analgesics work by stimulating receptors in the central nervous system (CNS). They also affect receptors in the intestinal tract, which is why they can cause nausea, vomiting, and constipation when they are used. Narcotics also affect the breathing center in the brain. For example, medications such as codeine are effective cough suppressants, but at higher doses, they can depress the respiratory drive. In fact, the reason people die from overdose is because they stop breathing. Stimulation of CNS opioid receptors by narcotics gives relief from severe pain. In addition, it can give a powerful feeling of euphoria. Illicit narcotics are designed to target this euphoric effect.

Narcotic drugs, such as heroin and morphine, are very effective in producing this effect early in their use. However, very quickly, the euphoric effects dissipate, and the user needs more of the substance to get the same effect (tolerance). There are behavioral effects and social conditions that push the user to seek the drug again (psychological dependence), but there is also an extremely powerful physical dependence that develops rapidly.

There are sensitive receptors and chemical neurotransmitters in the body, especially in the brain and gastrointestinal tract, that exist in a delicate balance. Narcotic analgesics can affect the sensitivity and the number of receptors, as well as deplete the neurotransmitters. This explains why withdrawal symptoms are so severe and wide-ranging. Acute withdrawal symptoms include profuse sweating, shaking, chills, rhinorrhea (runny nose), vomiting, and diarrhea. A dependent user in withdrawal will have hyperalgesia (severe diffuse pain and decreased pain tolerance) and hyperesthesia (sensitivity to benign stimuli such as noise and light). The hyperalgesia and depression symptoms can last for several months until the normal balance of receptor sensitivity and neurotransmitters is restored.

Withdrawal symptoms vary according to the medication used, its half-life, and the length of time it is used. Morphine and heroin have short half-lives and so have a rapid onset and relatively short duration. Withdrawal symptoms appear within a few hours after an addict's last fix. On the other hand, methadone has a very long half-life, and this is why methadone is used to wean people off narcotic dependence slowly. Withdrawal is gradual, and the symptoms do not appear early or rapidly.

Methadone binds opioid receptors in the body without producing intoxication. This not only prevents physical withdrawal symptoms but also prevents methadone from being used as a recreational drug of abuse. Because the opioid receptors are bound, a person who has taken methadone and then takes another narcotic will not experience the effect from the second drug. These characteristics allow methadone to be used to treat chronic pain and still allow people to function effectively. Medications such as methadone are considered partial opioid agonists.

Most narcotics are what the federal government calls Schedule II drugs. This means they are strictly regulated by the Drug Enforcement Agency (DEA). No more than a 30-day supply is given with any prescription, and automatic refills are not allowed. Possession of these substances without a prescription is a federal offense punishable by fines and a jail term. Of note, heroin is a Schedule I drug. This means heroin has no therapeutic benefit, and possession is only permitted in special, tightly controlled, and rare circumstances, such as scientific research. Some codeine preparations are available over the counter in Canada, Mexico, and some European countries.

Many common oral narcotics are a combination of medications. Narcotics are prepared with other analgesics such as acetaminophen (brand name when used alone: Tylenol, commonly abbreviated as APAP), aspirin (acetylsalicylic acid, or ASA), or ibuprofen (common brand names when used alone: Motrin, Advil). Oxycodone, a narcotic, plus acetaminophen is known by the brand name Percocet. Hydrocodone, a different narcotic, plus acetaminophen is marketed as Vicodin. These medications deliver their effects in about 15 minutes and last around 6 hours. They are commonly used in the treatment of fractures or in postoperative care. Abusing these medications can not only have the side effects of narcotic abuse, but there can be toxicity from the other medications in the pills. Acetaminophen toxicity causes liver failure, aspirin toxicity can cause bleeding and tinnitus (permanent ringing in the ear), and ibuprofen toxicity can cause kidney failure.

Oxycontin has made news in recent years because of increasing abuse and the aggressive efforts by addicts to get the medication, including pharmacy robberies. This medication is designed to give effective pain relief, with a slow release of narcotics over a 12-hour period. It is very helpful in conditions of chronic severe pain, such as certain kinds of cancer. Recreational drug abusers crush the pills and get the narcotic's concentrated effect all at once by ingesting, snorting, or injecting it.

Athletes are sometimes prescribed narcotic medications when recovering from injuries or surgeries. Interestingly, real pain has been found to be fairly protective in preventing tolerance or dependence when using narcotics. For the vast majority of patients, as the injury heals, the medication is used less and less and discontinued appropriately. For a very small percentage of people, personality, body chemistry, or indiscriminate prescribing by their doctor can contribute to dependence or abuse. Sometimes, athletes continue to use narcotics to train or compete through ongoing pain or as a mechanism to deal with stress.

If narcotic abuse is suspected or discovered, a caring, multidisciplinary team is needed to assist in recovery. This often includes a physician skilled in pain management, a psychologist and/or psychiatrist, and family and friends.

Michael O'Brien

See also Doping and Performance Enhancement: A New Definition; Doping and Performance Enhancement: Historical Overview; Doping and Performance Enhancement: Olympic Games From 2004 to 2008; Performance Enhancement, Doping, Therapeutic Use Exemptions; World Anti-Doping Agency

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Neck and Upper Back Injuries

Injuries to the neck (cervical spine) are not uncommon in contact sports, including rugby, hockey, and football. Up to 15% of athletes participating in football sustain some cervical spine injury. Unfortunately, a large majority of neck injuries result in catastrophic injury (death or permanent disability). Upper back (thoracic spine) injuries occur less often and are seen in sports such as gymnastics, wrestling, hockey, and football, as well as other contact sports.

Overuse injuries of the cervical and thoracic spine occur in noncontact sports. In children and adolescents, these overuse injuries may produce spinal deformity such as kyphosis (forward curvature of the back). Sports such as dancing, swimming, and diving appear to have a higher incidence of spinal deformities in young athletes. A possible explanation for this is that the immature spine is more susceptible to injury from the forces generated by sporting activity.

Anatomy

The neck and upper back play an important role in motion and support of the upper body and head. The neck, or cervical spine, provides motion and support for the skull. The upper back, or thoracic spine, allows for the transfer of forces between the upper and lower extremities. Together, the cervical spine and thoracic spine contain the spinal cord.

The flexible cervical spine is at greater risk of injury to the disks and bony structures because of its inherent mobility. The thoracic spine, however, is more rigid and isprotected by the rib attachments. The lower two ribs are unattached ("floating") and allow increased motion in the lower thoracic spine. Traumatic and overuse injuries of the spine are more common in the transition zones of flexibility at the lower cervical and thoracic spine.

The cervical vertebrae can be divided into the upper and lower cervical spine. The upper cervical spine consists of the occiput to C1 and the C1-C2 articulation. The atlas, C1, has a smaller arch in the front and a larger arch in the back, which are connected by the lateral masses. The axis, C2, contains the odontoid process, which articulates with the anterior arch of C1. It is held in place by the transverse ligament. Forty percent of cervical flexion and extension and 60% of rotation occur between the occiput to C1 and C1-C2 articulations.

The lower cervical spine is principally responsible for flexion and extension. The lower cervical spine consists of the C3-C7 vertebral bodies, separated by the intervertebral disks. The facet joints form the posterior border of the foramina and lie in a horizontal plane, allowing for rotation. In the thoracic spine, the facet joints are more vertical. The transverse process contains the vertebral artery foramen.

The size of the thoracic vertebrae gradually increases from T1 through T12. The heads of the ribs articulate with the facets on the vertebral bodies. The tubercles of the ribs articulate with the facets on the transverse processes. The thoracic facet joints are in a coronal orientation that allows for lateral flexion of the thoracic spine. There is a transition between the upper and lower thoracic vertebrae. The upper vertebrae resemble cervical vertebrae, whereas the lower thoracic vertebrae more closely resemble lumbar (lower back) vertebrae. An additional structure unique to the thoracic spine is the scapula (shoulder blade). The scapula is a triangular bone that lies between the second and the seventh ribs and projects 30° to 40° to the frontal plane. There are several fluid-filled sacs called *bursae,* which help in the movement of the shoulder blade over the posterior ribs.

From C3 through T12, each functional unit of motion acts as a tripod. The tripod consists of the disk anteriorly and the facet joints posteriorly. The intervertebral disk is composed of the annulus and ligamentous layers enclosing the gelatinous nucleus pulposus. The annulus consists of 10 to 20 layers of concentric, obliquely oriented ligamentous lamellae and provides torsional stability.

There are important anatomical differences in the spines of growing children. The annulus of the disk is attached to the growth cartilage of the epiphysis and apophyseal ring of the vertebral body. The epiphyseal growth plate forms the superior and inferior borders of the vertebral body. The epiphyseal growth plate consists of a cartilaginous end plate and the contiguous ring apophysis. This growth cartilage is susceptible to injury, particularly with repeated flexion and extension.

There are many paraspinal muscles associated with the cervical and thoracic spine. The anterior and middle scalene muscles are functionally important as they originate from the anterolateral cervical spine and attach to the first rib. The brachial plexus travels between the scalene muscles as it passes through the thoracic outlet. The brachial plexus can be impinged in the thoracic outlet as well as between the first rib and the clavicle.

Evaluation of Injuries

Injuries to the neck and back can be catastrophic injuries and should be considered as medical emergencies. If an athlete sustains a neck or upper back injury, he or she should not be moved until paramedics arrive. Paramedics should put a neck collar on the athlete and put the injured athlete on a rigid backboard for transportation to a hospital for further assessment. It is important to make sure that the athlete's airway and breathing are not affected by the injury. This should be assessed by qualified health care personnel (doctor, nurse, trainer, paramedic). If the athlete is unconscious, it must be assumed that there is a cervical spine injury, and the athlete's neck should be protected from any movement to avoid further injury.

Details of Injury

It is extremely important to obtain details of the mechanism of injury and associated symptoms when an athlete presents with a neck or back injury. Injuries may be acute or may have a more insidious onset. Details regarding age, gender, and sport/occupation are important to ascertain. Younger athletes are at risk for growth cartilage injuries, whereas older athletes are more prone to disk injuries. Certain conditions are associated with gender; for example, spondyloarthropathies are more common in males. Patterns of injury are associated with particular sports. For instance, disk and end plate injuries are common in gymnasts.

The mechanism of injury, the onset of pain (whether it was sudden or insidious), the location of the pain, as well as the quality of the pain and whether the pain radiates anywhere else are important to help determine the type of injury. Neck and back injuries may be associated with neurological symptoms, such as weakness, paralysis, or paresthesias (tingling sensation, numbness). Things that make the pain better or worse, such as body position and activities, can help suggest the type of injury. The quality of the pain can also suggest the type of injury. For instance, severe pain that shoots down the leg suggests compression of a nerve root.

With traumatic injuries, knowledge of the mechanism of injury and position of the head at the time of injury can help determine the location of injury. The most common injuries are hyperflexion injuries, which can cause compression fractures of the anterior vertebral body and tears of the posterior spinal ligaments. Hyperextension injuries can result in compression of the posterior spinal elements and tears of the anterior longitudinal ligament. Axial loading of the spine can result in compression or burst fractures of the vertebrae. Rotational forces may result in facet joint injuries.

Pain originating from the cervical spine may radiate into the arms or the shoulder blade region, whereas thoracic pain may radiate to the chest or to the legs. The presence of myelopathic symptoms, such as bowel or bladder incontinence, unstable gait, or weak hands, indicates an injury to the nerves or spinal cord. Some medical conditions, such as Down syndrome, can be associated with neck problems and may predispose athletes to neck injuries. It is important to know details of previous evaluation and treatment of neck and back injuries.

The presence of "red flag" symptoms should be elicited. These symptoms include night pain, weight loss, fever, structural deformity, gait disturbance, and inflammatory symptoms, such as morning stiffness. The presence of cauda equina syndrome, characterized by incontinence of bowel or bladder, loss of anal sphincter control, and saddle anesthesia, is a surgical emergency.

Physical Findings

An athlete with a neck or back injury may have bruising, swelling, or deformity of the spine. There is usually tenderness to palpation of the bony structures injured. The surrounding muscles in the neck and upper back may also be tender to the touch and may be in spasm.

Range of motion of the spine may be decreased, both actively and passively. Flexion and extension of the neck can be assessed by asking the athletes to put their chin to their chest and to look up at the ceiling. Lateral rotation of the neck can be assessed by asking the athletes to turn their chin to the right and left. Normal range of rotation of the neck is 60° to 80°. Side-to-side flexion is assessed by asking the athletes to put their right ear to their right shoulder and then their left ear to their left shoulder. Normal range of motion of lateral bending is 40°.

Range of motion of the thoracic spine is assessed with the athlete standing. The athletes are asked to bend forward and touch their toes. If pain is exacerbated by forward flexion, or if movement is limited secondary to pain, it may indicate injury to the anterior spinal elements, such as a vertebral body fracture or disk injury. Extension of the thoracic spine is assessed by having the patient bend backward with the examiner stabilizing the patient's hips. Pain that is exacerbated by extension suggests injury to the posterior spinal elements, such as the facet joints.

Certain provocative maneuvers of the neck can help identify the etiology of neck or upper extremity symptoms. The Spurling test elicits cervical root compression resulting from root pathology or narrowing of the exiting foramen. The Spurling test is performed by extending and rotating the athlete's neck toward the symptomatic side while applying an axial load. This position causes narrowing of the exiting foramen; a positive test reproduces the athlete's symptoms. The axial compression test is performed by applying an axial compressive force on the athlete's head. This maneuver causes narrowing of the intervertebral space and foramina. A positive test reproduces the athlete's pain and is suggestive of foraminal narrowing or disk pathology. The final provocative test of the cervical spine is the distraction test. The examiner applies vertical traction to the athlete's head. If symptoms are relieved by this maneuver, it suggests that the athlete's pain may have been caused by compression of the intervertebral disk or facet joints.

Special tests in an athlete with an upper back injury include springing of the ribs, in which the ribs are compressed toward midline by the examiner's hands. The athlete should be asked to inhale maximally as well as to cough/sneeze and to try to reproduce his or her symptoms.

A thorough neurologic examination is vital in any athlete presenting with a neck or back injury. Muscle strength testing may indicate weakness of specific muscle groups, which can point to the level of spinal injury. Muscle tone may be affected by spinal injuries. Increased muscle tone indicates an upper motor neuron injury or muscle spasm, whereas flaccid muscle tone suggests lower motor neuron injury or spinal shock. Deep tendon reflexes in the arms and legs may be increased or decreased in spinal injuries. Sensation may be decreased. The level of spinal injury can be determined by the distribution of any sensory defect.

Investigations

The four main methods of radiographic imaging include X-ray, computed tomography (CT) scan, magnetic resonance imaging (MRI) scan, and bone scan. Each method has its own strengths in evaluating the spine. It is important to keep in mind that imaging studies may reveal abnormalities that are not associated with the athlete's symptoms. For this reason, the choice of imaging should be specific and localized to the area of possible injury.

X-rays are most appropriately used to evaluate the bony structures of the spine and their spatial relationships to each other. Radiographs can be used as a screening tool to look for congenital malformations of the cervical and thoracic spine. They can also be used to assess injuries such as compression fractures, dislocations, and posterior element injuries. X-rays of the thoracic spine are not routinely indicated, however, as they do not usually add much to the clinical picture.

Radiographs of the cervical spine should begin with the lateral view, particularly in cases of trauma. A proper lateral view of the cervical spine should include all seven cervical vertebrae, C1-C7, and at least the top of T1. Visualization of the C7-T1 junction may be enhanced by arm traction or by a swimmer's view, in which one arm is elevated. If adequate visualization of this area is not possible with plain radiographs, CT may have to be performed.

Several bony relationships of the cervical spine should be assessed on lateral radiographs. There are four lines that need to be evaluated: (1) the anterior vertebral line, (2) the posterior vertebral line, (3) the spinolaminar line, and (4) the tips of the spinous processes. All these lines should have a smooth contour with parallel facets. An interspinous space greater than 10 millimeters (mm) is indicative of instability. In children, there may be a normal pseudosubluxation up to 4 to 5 mm at C2-C3, and sometimes at C3-C4, due to increased ligamentous laxity. The *atlantodens interval* (ADI) should also be evaluated on the lateral view of the cervical spine. The ADI should be less than 3 mm in adults and less than 4 mm in children less than 8 years of age. Another indication of possible spinal injury seen on the lateral view is the presence of retropharyngeal soft tissue swelling. Soft tissue swelling in excess of 6 mm at C2 and 22 mm at C6 in the adult indicates possible injury. In children, swelling in excess of 7 mm in the retropharyngeal space and 14 mm in the retrotracheal space is suggestive of spinal injury.

The anterior-posterior (AP) view of the cervical spine allows for assessment of scoliosis, lytic lesions, and congenital malformations. In the setting of trauma, a displaced spinous process may indicate a facet dislocation.

An open-mouth odontoid view should always be obtained when ruling out a cervical spine injury. This view allows for visualization of an odontoid fracture and signs of C1-C2 instability. Instability is indicated by more than 7 mm of lateral mass overhang or asymmetric dens position between the lateral masses.

Radiograph views of the thoracic spine should include AP and lateral views. The AP view assesses scoliosis and congenital malformations, as well as paravertebral soft tissue swelling. The lateral view of the thoracic spine assesses for kyphosis and changes consistent with Scheuermann disease. Normal thoracic kyphosis is up to 45° to 50°.

CT scan is the best imaging study to assess bony injury in detail. It can be used in trauma situations to assess spinal stability if the patient has mental status changes, if X-rays are inadequate, or there are subtle changes on X-ray. CT can also provide better definition of lytic or sclerotic lesions seen on radiographs.

MRI scan is the best study to assess soft tissues. It also offers good bone resolution without ionizing radiation. Any patient with neurologic symptoms or deficits on exam should have an MRI scan taken to evaluate for spinal cord injury. Disk herniations are also well defined on an MRI scan and can be classified as protruded (contained by the outer annulus), extruded (not contained by the outer annulus), and sequestrated (separated from the disk). However, MRI findings need to be correlated with physical findings and the patient's symptoms as abnormalities can be visualized on an MRI scan that are not necessarily contributing to the patient's pain.

MRI can elucidate subtle spinal cord injuries that are not seen on X-rays or CT. Children, particularly less than 8 years of age, may have significant spinal cord injuries without radiographic abnormality (SCIWORA). Patients who have myelopathy on exam despite normal radiographs or CT should have an MRI done to assess for spinal cord injury.

Bone scan can be used to assess for metabolic activity in bones. It can be used to assess for infection, fractures, stress reactions, tumors, and arthritis. In children, who are still growing, open growth plates will also "light up" on bone scan.

Types of Injury

Table 1 lists the types of neck and upper back injuries.

Table 1 Neck and Upper Back Injuries

Neck	*Upper Back*
Burners	Disk disease
Fractures	Muscle strain/contusion
Disk disease	Scheuermann kyphosis
Muscle strain/contusion	Scoliosis
Facet syndrome	Referred pain
Klippel-Feil syndrome	
Os odontoideum	

Prevention of Injury

Prevention of spinal injuries includes conditioning, proper sports technique, and proper safety equipment. Strengthening of the cervical spine and upper trunk is important to help absorb the forces involved in contact sports, such as hockey and football. Upper back strength helps improve cervical stability. Proper sports technique should be followed to help prevent injuries. Certain techniques have been associated with severe cervical injuries, such as spearhead tackling in football. Abolishing this technique has reduced the incidence of cervical spine injuries in this sport. In hockey, instituting the heads-up policy has reduced spinal injuries. Appropriate equipment can also help reduce injuries. For instance, well-fitted shoulder pads that prevent lateral flexion help reduce "burners" in football.

Table 2 Watkins Neurologic Deficit Rating System for Return to Play

Deficit	*Rating*
Canal narrowing	
>12 mm	1
>10 and <12 mm	2
10 mm	3
8–10 mm	4
<8 mm	5
Neurologic deficit	
Single-arm symptomatic	1
Bilateral upper extremities	2
Hemi-arm and leg symptoms	3
Transient quadriparesis	4
Transient quadriplegia	5
Duration of symptoms	
<5 minutes	1
<1 hour	2
<24 hours	3
<1 week	4
>1 week	5

Return to Sports

In general, an athlete must be painfree, with no neurologic symptoms, and have a full range of motion of the spine and normal strength before returning to sports. However, there are certain structural defects that may preclude athletes from participating in contact sports. Risk categories to determine return to play were developed by Watkins. The classification includes minimal risk, moderate risk, and extreme risk. Minimal-risk injuries imply little more risk than is usually involved in the sport. Examples of minimal-risk injuries include asymptomatic disk herniations, healed undisplaced fractures, healed surgical fusion, and single-level Klippel-Feil syndrome.

Moderate-risk injuries imply a reasonable possibility of recurrent injury. Examples of moderate-risk injuries include disk herniations associated with radiculopathy (radiating pain, weakness, tingling), three or more burners, a healed posterior single-level fusion, and a healed two-level anterior fusion.

Extreme-risk injuries imply a high risk of permanent injury with neurologic deficit. These injuries include Jefferson fractures, unhealed odontoid fractures, unhealed hangman's fractures, partially or fully ruptured transverse ligament of the axis, or any injury with neurologic deficit. Athletes who have sustained extreme-risk spinal injuries should not continue to participate in contact sports.

A unique situation in making return-to-play decisions involves athletes who have suffered a transient neurologic deficit and have spinal stenosis. R. G. Watkins developed a rating system that takes into account the amount of canal narrowing, the extent of neurologic deficit, and the duration of symptoms (Table 2). The total score is determined by adding these three scores. A total score of 6 or less is classified as a mild episode; a score of 6 to 10 is classified as a moderate risk episode; and a score of 10 to 15 would be classified as a severe episode. Regardless of the score, any neurologic deficit should preclude an athlete from returning to sports.

Laura Purcell

See also Catastrophic Injuries; Fieldside Assessment and Triage; Neck Spasm; Torticollis, Acute

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Neck Spasm

The occurrence of neck spasm suggests an injury to the muscles of the neck. Because the muscles of the neck have a low threshold for spasm, the causes of spasm may vary. Because of the importance of the neck in posture, nervous system functions, and activities of daily living, a careful and accurate differential diagnosis is essential.

Neck Strain

Neck strain suggests an injury to the ligaments of the neck, either between the spinous processes as in a whiplash injury or, less commonly, in the ligaments holding the body of the vertebrae in alignment. In all cases, this leads to muscle spasm, which can make diagnosis difficult. The question becomes, "Is this the muscle causing the pain, or is it the muscle protecting an injury that is causing the muscle to spasm?"

Neck Pain in Sports

Neck injury most commonly occurs in contact sports, especially in football, where improper coaching or an ill-timed slip may lead to malpositioning of the neck during a tackle. Athletes in diving and water sports, wrestling, hockey, skiing, gymnastics (especially trampoline), soccer, martial arts, cheerleading, and weight lifting are prone to neck injury.

Anatomy

The neck is formed by seven cervical vertebrae. Vertebrae are bones that create structure, allowing movement in some directions and restricting or limiting movement in others. They are separated by intervertebral disks, which serve as cushioning and help with dissipation of energy when the vertebrae are compressed. The *zygoapophysial joints* in the neck, also called the facet joints, are the joints that connect the vertebrae to each other. They are positioned in pairs, with one on each side of the vertebra connecting with the vertebra below and one on each side connecting to the vertebra above. Both intervertebral disks and facet joints are named by the vertebrae they connect. Because there are seven cervical vertebrae, the disk between the fourth and fifth vertebrae is called the C4-C5 disk, and the facet joint at that location is called the C4-C5 joint.

The vertebrae also create a space for the spinal cord, the *vertebral foramen*, which both the muscles and the bones in the neck work to protect. The peripheral nerves to both the neck and the arms extend from the spinal cord as it passes through the cervical vertebrae, and then these nerves pass through lateral openings in the cervical spine called *intervertebral foramina*. The muscles of the neck are numerous, with a posterior superficial, intermediate, and deep layer of muscles. The anterior muscles of the neck work to protect the neck, much like the abdominal muscles protect the lower back. The important muscles of the shoulder that connect to the neck include the trapezius, the levator scapula, the rhomboid minor, and the serratus posterior superior muscle.

Causes

The most common injuries to the neck muscles or ligaments are caused by motor vehicle accidents. Sports injuries and prolonged poor position of the neck during sleep or at work are also common precipitating factors. When the injury is to the muscle only, the muscle will heal within 2 to 3 weeks. If the muscle is protecting an injury to something else, or an infection, the spasm will tend to persist. In whiplash injuries, the injury is to the ligaments between the vertebrae. When the injury is to the facet joints, the muscles will spasm to keep the joints apart, as this reduces the pain from joint inflammation. If the injury is to the spinal cord, intervertebral disk, vertebrae, or peripheral nerves or is caused by infection, the muscles will spasm to keep the neck in an optimal position to create as much space for the spinal cord as possible. Sometimes the injury is actually to the shoulder, but because of muscle attachments and muscle spasm thresholds, the pain is felt more in the neck.

Symptoms

Neck strain is manifested by muscle spasm or tightness throughout the neck. Most commonly, this is posterior, but it can also be an anterior spasm. When the pain is from the cervical facet joints, the patient reports grinding and cracking through the neck on awakening, then as the muscles begin to fire to pull the joints apart, the pain diminishes. Then as the muscles begin to tire from pulling the joints apart, muscle spasm begins, and the patient reports typical pain in the neck from this spasm. Patients with injury to the spinal cord or peripheral nerves (commonly from bulging of the intervertebral disk into the nerve) will report pain, numbness, and/or weakness in the arms that correspond to the affected nerve when the neck is moved. When the injury is actually in the shoulder, faulty motion of the shoulder blade (scapula) causes irregular tightness or spasm of the muscles trying to control this scapula, and as these muscles attach to the neck, they cause neck pain. This, however, is where neck pain gets complicated. Disk bulges in the neck can lead to weakness in the shoulders, which in turn leads to pain in the neck. Prolonged muscle spasm in the neck from facet joint inflammation can lead to weakness in the shoulder from deconditioning, which can lead to neck pain. In general, prolonged neck pain leads to shoulder pain, and prolonged shoulder pain leads to neck pain. To further this diagnostic dilemma, thoracic outlet symptoms can mimic intervertebral disk bulging. When a patient has neck pain, spasm of the scalene muscles in the neck (which are deep muscles that go from the cervical vertebrae to the first and second ribs) can cause impingement of the nerves to the arms, resulting in pain, numbness, and/or weakness in the arms. When a patient has shoulder pain, he or she often will have tightness of the pectoralis minor muscle anteriorly, as it also attempts to control the motion of the scapula. The nerves to the arms also pass under this muscle, and this can cause radicular symptoms, but they are a type of thoracic outlet. Poor posture from either neck or shoulder pain can cause the clavicle and the first rib to affect the nerves to the arms as they pass between these two bones, again leading to confusing arm symptoms.

Where the muscles in the neck attach to the head is called the nuchal ridge of the skull. At this connection, the muscles intermingle with a muscle called the epicranius. This muscle covers the top of the skull like a cap, and if it starts to spasm, the patient will develop a common tension headache. Also, at the nuchal ridge is a pair of nerves on either side of the head called the greater occipital nerve (GON) and the lesser occipital nerve (LON). Prolonged spasm of the neck muscles can lead to irritation of these nerves. If the GON is irritated, the patient will get pain over the top of the head that feels like it is coming out of the eye. If the LON is irritated, the patient will get pain that goes over the top of the ear to the temple area.

If the patient has redness, swelling, or fever, with bracing of the neck, infection or meningitis must be ruled out. If the patient has recent trauma with persistent bracing of the neck, X-ray and/or computed tomography (CT) scan must be done to rule out vertebral fracture.

Diagnosis

When neck strain is acute and present after trauma, X-rays and CT scans may be indicated. When neck strain is present with symptoms of meningitis or infection, appropriate labs, spinal taps for analysis of cerebrospinal fluid, and magnetic resonance imaging (MRI) scan may be indicated. When radicular symptoms in the neck or arm are present, a physical exam to rule out thoracic outlet syndrome, along with detailed examination of the arm for dermatome, reflexes, and muscle strength abnormalities, must be completed. An MRI may be necessary, but one must keep in mind that in some studies, up to 60% of people with no symptoms at all displayed a disk bulge/herniation on an MRI scan. Examination of the shoulder is imperative, with special attention to motion of the scapula, and palpation of the muscles that pass from the scapula to the neck, along with symptoms of impingement in the shoulder. Palpation of the facet joints in the neck should be attempted, recognizing, however, that if the muscles are spasming, they overlie the facet joints and this palpating has a high false-positive rate. Full range of motion of the neck should be requested, allowing the patients to move themselves, as patients will rarely severely hurt themselves.

Treatment

In acute neck spasm/strain, when infection, fracture, and radicular symptoms have been ruled out, the muscles are treated with rest and ice—two elements of the common RICE or PRICE (*p*rotect, *r*est, *i*ce, *c*ompression, and *e*levation) therapy. Compression of the neck may be unwise, and elevation of the neck may be unnecessary. Protection with a soft or hard collar is the preference of many treating practitioners. Rest of the neck muscles should follow the same protocol as for the lower back, where it is wise to rest for a short while but return to activity after a day or two is better for the patient. Ice should be applied to the muscles of the neck using the accepted 20-minutes-on/2-hours-off protocol. Anti-inflammatories are encouraged if used according to the manufacturer's recommendations. If the physical exam suggests an intervertebral disk bulge/herniation, and MRI confirms it, then an epidural steroid injection and/or surgery to the disk may be warranted. If the cause is facet joint pain, then steroid injections to the facet joints or the nerves that supply these joints may be necessary. Surgical fusion of these joints is also sometimes needed. If the spasm is from the shoulder, physical therapy is often the best option, but again, this is a confusing scenario, and the practitioner must be diligent to unravel this puzzle. If the patients are not taught correctly how to strengthen the motion of the scapula, then they will continue to use their compensatory muscles, and their neck pain will worsen. Thoracic outlet symptoms as described above can also be improved with stretching of the pectoralis minor and scalene muscles and improvement of posture. All this is best achieved with appropriate physical therapy. Once a person has more than a few days of neck pain from either strain or spasm, he or she will develop weakness of the muscles in the anterior neck and tightness in the muscles of the posterior neck. This usually leads to future and further neck problems. Every effort should be made to strengthen the recovered neck's anterior muscles and to stretch the posterior muscles. Injury should also alert the practitioner, coach, parent, and athlete that a careful review of technique, style, and current strength and habits must be undertaken to avoid a repeat of current symptoms and to prevent an even worse injury.

Sean M. Wheeler

See also Neck and Upper Back Injuries; Torticollis, Acute

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Neurologic Disorders Affecting Sports Participation

Neurologic disorders are conditions that affect the nervous system. Since the nervous system is the part of the body responsible for decision making and coordination, as well as planning and executing movement, disruptions in its function can have significant effects on the ability to perform athletically. Certain neurologic conditions can potentially be made worse through participation in sports. At the same time, the presence of other neurologic conditions can make playing sports unsafe. This entry discusses some of the more common neurological conditions that may affect sports participation. More detailed discussion of these diseases or conditions can be found in other entries in this encyclopedia.

Anatomy

For purposes of discussion, the nervous system can be divided into two components, the *central nervous system* and the *peripheral nervous system*. The central nervous system includes the brain, brainstem, and spinal cord. The peripheral nervous system begins with the *nerve roots* that exit the spinal canal. The nerve roots feed into complex networks that then form the *peripheral nerves*, which carry out the functions of the body. The *cranial nerves* are specialized peripheral nerves that are formed in the brainstem and not only provide much of the functions of the head but also serve certain physiological processes.

Central Nervous System Disorders

Aneurysm

An aneurysm is a deformity of a blood vessel that occurs when that vessel's walls are weakened. The weakened wall causes a balloon-like deformation in the vessel, sometimes compared with a bubble in a garden hose. Aneurysms in the brain are most commonly found in the vascular structure called the *circle of Willis* at the base of the brain. Depending on the size and particular location of the aneurysm, surgical or catheter intervention is warranted. Conversely, some aneurysms do not require treatment. Participation in sports, especially contact sports, may increase the risk of certain aneurysms, bleeding, or rupturing. Consultation with a neurosurgeon is essential to determine the safety of participation.

Arteriovenous Malformation

Arteriovenous malformations (AVMs) occur when the natural organization of how arteries and veins connect to each other is compromised. As with aneurysms, certain AVMs in the brain may represent a bleeding risk that is significant. The size and location of the AVM can help determine the safety of playing sports. Again, neurosurgical consultation is essential.

Concussion

Perhaps the most common neurological condition caused by athletic participation, *concussion* can be defined as a disruption in normal brain physiology as the result of a force applied to the brain. If an athlete experiences a trauma that causes any symptoms of concussion, including headache, disorientation, nausea, memory difficulties, loss of consciousness, unsteadiness, or personality changes, he or she should be removed from competition immediately and evaluated by a physician, a certified athletic trainer, or an emergency medical technician. Continuing to participate after concussion can lead to worsening of symptoms or even death.

Epilepsy

Epilepsy is defined as having more than one unprovoked seizure. A seizure occurs when the normal neuronal activity of the brain is interrupted by excessive or synchronous activity. A single seizure can occur as a result of trauma and does not necessarily mean that the individual in question has epilepsy. The diagnosis of epilepsy should be made by a neurologist. Physical exertion to the point of dehydration or electrolyte imbalance can lead to a seizure in a person with epilepsy. Athletes with epilepsy can participate in the vast majority of sports as long as their epilepsy is under good control with medication. The only sports that may require further consideration involve the same risks that are inherent to that activity outside the sporting arena, such as swimming alone or performing tasks at heights.

Intracranial Hematoma

A *hematoma* is a collection of blood outside the blood vessels, the result of a hemorrhage into the surrounding tissues. An athlete who has experienced an episode of bleeding in or around the brain should have a complete evaluation done by a neurologist or neurosurgeon prior to participating in sports. Depending on the sport in question and the cause of the bleeding, participation may not be ruled out.

Migraine Headache

Extremely common, especially in college-age women, the typical migraine headache produces a pounding, focal head pain with concurrent nausea and sensitivity to light, which lasts from a few hours to a few days. Exertion can be a trigger for migraine headache in athletes. Athletes who experience migraine headache typically have greatly reduced physical performance. Migraines can be treated with acute medications, namely, the triptan class. Neurological consultation may be warranted.

Multiple Sclerosis

Multiple sclerosis (MS) is a disease that affects the brain or spinal cord primarily through the process of *demyelination*. The connections between neurons are interrupted, and a loss of function ensues, typically causing numbness, weakness, or visual disturbance. Increased body temperature can make the symptoms of MS worse, but participation in sports is not generally a problem, as long as the symptoms of the disease do not interfere with the ability to perform adequately.

Spinal Stenosis

A *stenosis* is an abnormal narrowing of a canal or passage. If the spinal canal is narrowed, either as a result of injury or disease, or as a congenital condition, contact sports may be hazardous. Symptoms may include recurrent neck pain, extremity pain, numbness, or weakness. Consultation with a neurologist or neurosurgeon is warranted.

Peripheral Nervous System Disorders

Plexopathy

Each extremity has a corresponding *plexus*, or network, of nerves near where it articulates with the trunk. If the plexus is impinged, stretched, or otherwise damaged, neurological symptoms can occur, including pain, numbness, or weakness in the extremity. Trauma is the most common cause. Athletes with plexopathy should not return to participation until they are completely asymptomatic.

Radiculopathy

Radiculopathy refers to a process that involves the nerve roots. The most common type of injury to the nerve roots involves compression from a vertebral disk. Symptoms included pain in the neck or back that radiates into an extremity. Diagnosis can be made with magnetic resonance imaging (MRI) of the area and/or with an electromyogram (EMG). Repetitive physical trauma can be a risk factor. Depending on the amount of damage, surgical intervention may be warranted. If not, rest is essential to recovery.

"Stingers," Burners

The common term "stinger" or burner refers to a trauma-induced pain, with possible transient loss of neurological function, in the affected arm. They occur, typically, as the result of either a stretch injury to the *brachial plexus* (mentioned above) or a compression injury of a nerve root. In either case, athletes with continued symptoms should not return to participation. Repetitive stingers can have an additive effect, making the next injury easier to incur and with more severe symptoms. Treatment depends on the suspected mechanism, but rest is almost always beneficial.

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See also Concussion; Head Injuries; Intracranial Hemorrhage

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Nonsteroidal Anti-Inflammatory Drugs (NSAIDs)

Sports injuries are often attributed to "inflammation." Consequently, the treatment recommendation regularly includes "anti-inflammatories," or *nonsteroidal anti-inflammatory drugs* (NSAIDs).

However, inflammation is not the primary pathology of injuries in sports. Furthermore, when a person injures a tendon, a ligament, or a bone, inflammation may be necessary for the injury to heal. Since NSAIDs are known to have serious gastrointestinal (GI) toxicity and a variety of other side effects, it is recommended that they be used only after consideration of the pathophysiology of the injury and with the understanding that their main benefit may be due to their analgesic and not their anti-inflammatory properties.

NSAIDs: Mechanism of Action

NSAIDs are used for their analgesic, anti-inflammatory, and antipyretic properties. Their therapeutic actions are believed to result primarily from their ability to block the formation of certain types of prostaglandins through inhibition of the cyclooxygenase (COX) enzymes. COX-1 catalyzes the production of several prostaglandins with protective functions such as coating the stomach lining with mucus and aiding platelet aggregation. COX-2 catalyzes the conversion of arachidonic acid into inflammatory prostaglandins. Inflammatory prostaglandins are involved in three key biological functions: sensitizing skin pain receptors, elevating body temperature through the hypothalamus, and recruiting inflammatory cells to injured body parts.

The Role of Inflammation in the Healing Process

The major rationale given for the specific use of NSAIDs in the treatment of musculoskeletal injuries is their anti-inflammatory qualities. An injured tissue is painful and often swollen; the term *inflammation* implies pain and swelling. Thus, the common treatment for the injured tissue is to administer an anti-inflammatory drug. What is perhaps insufficiently recognized, however, is that inflammation, in addition to being a sign of injury, is a necessary step in the healing process.

The body responds to injury through a sequence of events. Whether the injured tissue is a ligament, tendon, or muscle, the process begins with an influx of inflammatory cells and blood. The inflammatory cells remove debris and recruit cytokines and other growth factors to the site of injury. This "inflammatory phase" is partly mediated by the same prostaglandins that are blocked by the NSAIDs. In a healthy healing process, a "proliferative phase" naturally follows the inflammatory phase. The proliferative phase consists of a mixture of inflammatory cells and fibroblasts. The fibroblasts build a new extracellular matrix and persist into the final phase of repair, the "maturation phase," where functional tissue is laid down. The key point is that each phase of repair is necessary for the subsequent phase. By blocking the inflammatory phase, NSAIDs can, at least theoretically, delay the healing of musculoskeletal injuries.

NSAIDs and Sports Injuries: What Is the Evidence?

NSAIDs are commonly prescribed for the treatment of musculoskeletal complaints such as muscle injuries, ligament sprains, tendon injuries, low back pain, and osteoarthritis. However, an examination of the pathophysiology and healing of such injuries, as well as a remarkable dearth of clinical trials supporting the efficacy of NSAIDs, calls into question their use in many treatment protocols.

Muscle Injuries

Muscle injuries, whether via direct trauma or excessive strain, have been found to be the most common of all sports-related injuries. Although NSAIDs are commonly recommended in treatment protocols, clinical studies documenting their efficacy are notably lacking. Anti-inflammatory treatment for muscle strains, contusions, and delayed-onset muscle soreness generally finds small, if any, benefit when compared with placebo.

Clinical outcome studies of muscle injuries are difficult to conduct as the injuries tend to heal within days without intervention. There is concern that through inhibition of the inflammatory pathway, NSAIDs may delay the rate of muscle fiber regeneration. While some animal studies suggest that this occurs, it is not clear that there is a deleterious effect in humans. Biologic tissue often heals best with mobilization. If the pain relief provided by an NSAID allows more movement, then the benefit of movement may outweigh the downside of interrupting the healing pathway.

Ligament Injuries

A variety of studies have been conducted on the effect of NSAIDs on the strength of rat ligaments after injury. The majority of these have shown no effect on ligament strength. Studies in humans have generally shown NSAIDs to be effective for pain relief and return to activity. However, as with muscle injuries, controlled mobilization is beneficial in ligament healing. The studies in humans have been done comparing NSAIDs with placebo. In this context, if NSAIDs decrease pain and thus encourage activity, they may provide some therapeutic benefit. It is unknown whether a similar effect could be obtained with other analgesics, including simply ice.

Tendon Injuries

When it comes to the treatment of tendon injuries, the argument to use NSAIDs because of their anti-inflammatory agents becomes especially controversial. Contrary to the name historically given to tendon injuries, *tendinitis*, these injuries do not seem to have a strong inflammatory component. (*Note:* The suffix *itis* denotes an inflammatory process.) Several leading researchers in tendon injuries have pointed out this misnomer and emphasized its unfortunate effect of furthering a false perception that an anti-inflammatory medicine should be used in treatment.

Studies with a large number of subjects have looked at tissue biopsies from chronic injuries of the extensor carpi radialis brevis tendon (the site of "tennis elbow"), Achilles tendon, patellar tendon, and rotator cuff tendons. Results show the tendons to be degenerative in quality and lacking in inflammatory cells. Thus, a more proper term would be either *tendinosis*, meaning tendon degeneration, or *tendinopathy*, signifying nonspecific tendon pathology. Some have argued that a poor inflammatory process is the precipitant causing tendon degeneration. Recent research is finding that abnormal tendon vascularity is associated with tendon pain.

Reviews of studies comparing NSAIDs with placebo have found the results to be inconsistent, with some showing a benefit and others showing no difference. A systematic review of studies evaluating NSAID use in lateral epicondylitis of the elbow (or tennis elbow) found that, as compared with placebo, NSAIDs provide a short-term benefit for pain and function. It is unclear if there is any long-term benefit of NSAIDs over placebo. Furthermore, it is unclear if NSAIDs offer a benefit over other pain relievers, physical therapy, or other treatment options. Given the state of current research, when NSAIDs are prescribed, the rationale should be their analgesic and not their anti-inflammatory properties.

Bone

Of all the common structures injured in sports, bone is the one where the use of NSAIDs has been questioned most vigorously. NSAIDs inhibit the prostaglandins that are known to be important for the repair of injured bone. Numerous studies in animals have shown that NSAIDs impair fracture healing, including the healing of stress fractures. NSAIDs are used to decrease the formation of *heterotopic ossification* (i.e., new bone formation in nonbony tissue). Human studies evaluating the effects of NSAIDs on bone healing have primarily been retrospective, looking back on poorly healing fractures. These studies have generally found NSAIDs to be associated with poor fracture repair. Being retrospective, cause and effect cannot be definitively determined. No studies have evaluated the effects of NSAIDs on stress fractures in athletes. The research to date suggests, however, that NSAIDs should be discouraged in patients suffering from fractures that are at risk of delayed healing.

Side Effects of NSAID Use

The decision to use any medication must be made only after considering the potential for side effects. The two most well-described side effects of NSAIDs are those on the GI tract and the cardiovascular system. Although NSAIDs were originally marketed as the safe alternative to aspirin, it quickly became apparent that NSAIDs themselves have serious GI side effects (e.g., GI bleeding). Dyspepsia (upset stomach) is another common side effect. Of importance, the symptom of dyspepsia should not be used as a screening tool for the potential for GI bleeding. Among patients who suffer GI bleeds, less than half will have had dyspepsia prior to the bleed. This might be due to the analgesic effect of NSAIDs. Perhaps as a result of the drugs' inhibition of platelet aggregation, individuals who suffer

GI bleeds while taking NSAIDs have a significantly higher mortality than those with GI bleeds who are not taking NSAIDs.

In the late 1990s, the COX-2 inhibitors were marketed as a safe alternative to NSAIDs. The COX-2 inhibitors preferentially block the COX-2 enzyme (thus blocking the inflammatory prostaglandins) while allowing the homeostatic properties catalyzed by COX-1 to proceed. The intent was to have medications that maintained the benefit of NSAIDs while reducing the side effects in the GI system and the peripheral vascular system. Evidence has shown that COX-2 inhibitors are preferred to nonselective NSAIDs for the purpose of decreasing GI bleeding. However, use of COX-2 inhibitors was severely curtailed once research showed an association between COX-2 inhibitors and myocardial infarctions (perhaps a result of increased platelet aggregation). This resulted in the removal of several COX-2 inhibitors from the market and strict warnings on those that remain. Of note, there is also some concern that nonselective NSAIDs may also increase the risk of myocardial infarctions, and this question continues to be investigated.

For the younger and active sporting community, the major GI and cardiovascular side effects are less of a worry. Still, NSAID use in athletes has been associated with adverse effects. A recent study in Finland found that approximately one in five young athletes reported minor side effects while using NSAIDs. NSAIDs affect the renal and cardiovascular systems, as prostaglandins are necessary for renal blood flow and the secretion of sodium and chloride. Prostaglandin inhibition has been shown to raise mean arterial blood pressure an average of 3 to 5 millimeters of mercury pressure (mmHg). Endurance athletes are often hypohydrated as a consequence of prolonged training. Prostaglandin inhibition can cause further decreases in renal blood flow. Case reports have discussed NSAID use as a potential factor in cases of acute renal failure in endurance events. A side effect that is important when working with competitive athletes is the effect of NSAIDs on the respiratory system. Blocking COX can shunt arachidonic acid toward the formation of the bronchoconstricting leukotrienes. It is estimated that approximately 1 in 10 asthmatics experience a decline in respiratory function as a result of NSAID inhibition of COX.

Conclusion

In recent years, the treatment paradigm for sports injuries has become more complicated. Historically, many injuries were attributed to inflammation, and the recommendation was for rest and an anti-inflammatory medication. However, basic science research regarding the healing of tissue, from muscle to tendon to bone, has called this historical model into question. In most cases, it does not appear that inflammation is a primary component of the injured tissue. Furthermore, when present, inflammation may be a necessary part of the healing process.

These investigations have had a direct bearing on current discussions of how best to treat the athlete with an injured body part and associated pain. In terms of injury healing, there is research supporting controlled mobilization as opposed to rest, as applied to a variety of muscle, ligament, and tendon injuries. Certain fractures may heal faster with gentle compressive forces as compared with complete bone immobilization. For the pain present while the injury is healing, no single recommendation can be made. Acetaminophen has been marketed as a possible pharmaceutical analgesic in the sports medicine community. Although initially believed to have no effect on COX enzymes, evidence is accumulating that COX enzyme inhibition is part of their mechanism of action. Topical NSAIDs are showing promise in treating the pain of sports-related injuries. There appears to be negligible systemic absorption and thus minimal concern for serious side effects. Oral NSAIDs remain excellent pain relievers, and short courses of NSAIDs are likely have no detrimental effect on most injuries.

Steven D. Stovitz

See also Pharmacology and Exercise

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Nose Injuries

In contact sports, the athlete's nose is at risk in a collision with another player or piece of sporting equipment, and being struck on the bones in one's face can be very painful. A blow to the nose can be frightening, especially because such injuries tend to bleed profusely, even in the absence of more extensive damage to the surrounding tissues. This entry describes common nasal injuries in sports and their treatment.

Epistaxis (Nosebleed)

More than 90% of all nosebleeds are anterior, usually from the Kiesselbach plexus in the Little area of the anterior septum. The first step to stop the bleeding is to sit or lie down with the head and shoulders higher than the waist and legs. Tilting the head forward will help prevent blood from pooling in the posterior pharynx, which can help prevent nausea and airway compromise. Mild epistaxis may resolve spontaneously without any intervention. Persistent cases should be treated with the application of direct pressure to the septum over the area of bleeding. If possible, place an ice pack on the nose and another ice pack on the back of the neck while applying direct pressure. The athlete should breathe through the mouth until the bleeding slows down. Return to play should not be allowed until the bleeding has completely stopped. If the bleeding has not diminished in 15 minutes by the clock, repeat the process for another 15 minutes. If nasal bleeding has not stopped after 30 minutes of appropriate management, further evaluation and referral to a hospital or specialist may be needed.

Cautery may be considered if direct pressure fails and the bleeding can be identified (silver nitrate or electrocautery). A simple pledget treated with petroleum jelly may be inserted or gently screwed into the affected nostril. Nasal packing may be used for compression if bleeding cannot be stopped by simpler means and the bleeding sites cannot be identified easily. Complications of nasal packing may include septal hematoma, nasal abscess, sinusitis, neurogenic syncope during packing, and pressure necrosis. While strenuous activity and return to play should be restricted with nasal packing in place, if no packing is required and the bleeding is controlled with ice and compression, the athlete may return to play. Failure of bleeding to stop with the measures discussed above may be a sign of epistaxis of a posterior origin. Most posterior bleeds require more than on-the-field assessment, and referral to a hospital or specialist for emergent hemostasis may be required.

Nasal Hematomas

Blunt trauma to the nose may rupture the blood vessels and result in the formation of a hematoma, a localized swelling filled with sequestered blood. The clinician must distinguish hematomas from simple swelling and ecchymosis (bruising), both of which tend to hide or obscure underlying injuries to the nasal skeleton. The accumulation of blood between the septal cartilage and the overlying tissue (mucoperichondrium) can produce adjacent tissue necrosis due to destruction of nasal cartilage, which depends on the blood supply from the overlying skin for nourishment. Overlying hematomas interfere with the transport of oxygen and nutrients and are prone to abscess formation. Septal hematomas can lead to pressure necrosis of the underlying bone and cartilage, causing collapse of the nasal dorsum, with resultant "saddle nose deformity" if not properly treated. Decompression with prompt aspiration should be done as soon as possible, with prophylactic antibiotics and nasal packing bilaterally to prevent recurrence. A simple test for septal hematomas is to take a cotton swab and feel any mass noted on the nasal septum for fluctulence. The nasal septum should not be fluctulent, and a nasal septum with a bluish tinge is characteristic of septal hematoma.

Lacerations

Nasal lacerations should undergo primary closure. All foreign material should be cleaned from the wound at the initial evaluation, using a scrub brush if necessary, to prevent scarring. Lacerations of the nose can be closed with 5-0 and 6-0 sutures and/or with steri-strips if appropriate. If any underlying cartilage is involved, antibiotics and referral may be appropriate. If the laceration is minor and can be stabilized well with steri-strips and/or sutures, the athlete may return to competition, provided the wound is not bleeding and is protected with an occlusive dressing. Subsequent participation requires similar nasal protection until healing is complete.

Nasal Fractures

Isolated nasal fractures are the most common sports-related facial fracture. The prominence of the nose and its low impact tolerance and thinness make it especially susceptible to injury. These fractures are less common in children because their nasal bones are less prominent and more flexible.

Clinical diagnosis of a nasal fracture is based on an accurate history and thorough physical examination. The severity may range from a slightly depressed greenstick fracture (commonly seen in adolescents and children) to displacement and/or disruption of the bony and cartilaginous components of the nose. Direct end-on trauma usually results in comminuted fractures of both the bone and the cartilage. Side blows may result in simple fractures with deviation to the opposite side. The most common signs of nasal injury are (in order of frequency) epistaxis, swelling of the nasal dorsum, ecchymosis around the eyes, tenderness of the nasal dorsum, radiographic evidence of fracture, obvious nasal deformity/asymmetry, and nasal bone crepitus. Radiographic evaluation is seldom helpful for immediate treatment decisions but may include an anteroposterior/lateral/oblique film series with a Waters view if necessary. Films are positive only about 40% of the time with a definitive fracture.

Swelling and ecchymosis may preclude an adequate examination. In this case, it is better to wait and reexamine the patient after the ecchymosis and swelling have improved. Nondisplaced fractures do not require reduction. Reduction of a displaced nasal fracture may be attempted immediately before swelling makes an adequate assessment of nasal deformity difficult. Ear, nose, and throat (ENT) follow-up is suggested within a few days for children and within 7 to 10 days for adults. Immediate follow-up is not required for routine fractures. All nasal septums must be adequately visualized during the initial examination to rule out septal hematoma, which requires immediate treatment as previously mentioned. It is always important to rule out other facial injuries, eye injuries, or head trauma that may have occurred in addition to the nasal injury.

Workouts and strenuous exercises are to be restricted if the patient has intranasal packing, which may last 3 to 4 days. Athletes should not return to play the same day unless there are absolutely no other associated injuries and the nose can be protected. Return to play is typically not advised, and the athlete should be restricted to noncontact drills for the first week postreduction, unless the nose can be adequately protected with external protective headgear.

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See also Craniofacial Injuries; Head Injuries; Protective Equipment in Sports

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Nutrition and Hydration

Sports participation continues to be increasingly popular, with people of all ages and abilities training and competing in athletic events. Among the factors that contribute to success in sports are nutrition and hydration of the athlete; indeed, proper nutrition forms the basis of training and performance. Furthermore, an athlete's needs change throughout the life cycle, making it important to consider not only the short-term goal of optimal training and performance but also the mid- and long-term goals of optimal growth and development and a healthy adulthood. This entry discusses and offers recommendations for the nutrition and hydration of athletes.

There are a few basic differences between general and sports nutrition. Athletes have essentially the same nutrition needs as nonathletes, but there are four ways in which the nutritional needs of athletes may differ from those of the general sedentary population. First, although the specific needs of the three macronutrients—carbohydrate, fat, and protein—appear to have the same percentages in the diet (approximately 60% carbohydrates, 25% fat, and 15% protein), the total amount of calories required by athletes may be slightly or much greater depending on the sport. Furthermore, micronutrients (including vitamins and minerals) may also be required in greater amounts. Second, athletes benefit from consuming the right forms of nutrition during training and competition. These nutrition and hydration needs differ from pre-event nutrition. Third, athletes have different nutrition and hydration needs for postworkout recovery. Fast and complete postworkout nutrition and rehydration are vital for maximizing the benefits that an athlete gets from a recently completed workout and maximizing performance in the next workout. Finally, there is considerable research regarding the potential benefits of performance-enhancing supplements. Whereas nutritional supplements are not necessary for optimal health, certain supplements may enhance sports performance to a level that foods cannot match. As yet, scientists have not singled out any one supplement for athletes, but various supplements have shown benefits in select studies. All four of these potential differences are considered in the following sections.

Carbohydrates

Good sports nutrition requires a consideration of macronutrients, micronutrients, balance and distribution of the diet, sport-specific concerns, and hydration. Macronutrients include carbohydrates, protein, and fat. Carbohydrates provide a major source of fuel for the body, as well as being the chief storage form of energy. They provide dietary fiber that is important for gastrointestinal health, regulating cholesterol and stabilizing blood glucose. Adequate carbohydrates in the diet, as well as stores in the muscles and liver in the form of blood glucose and glycogen, is of primary importance for optimal sports nutrition.

Carbohydrates should be consumed before, during, and after exercise. Prior to exercise, carbohydrates provide energy to maintain daily activities of living, as well as a pool of calories to spare, or make available protein for muscle growth and repair. In addition, carbohydrates before exercise help maintain optimal stores of muscle and liver glycogen. Glycogen in muscles is the main source of carbohydrates in the body, while liver glycogen helps maintain blood glucose levels both at rest and during exercise. When an athlete is at rest, the brain and central nervous system use most of the blood glucose. During exercise, muscles use more glucose, even up to 30 times more, depending on the intensity and duration of the exercise.

Carbohydrate guidelines for the general public are often expressed as a percentage of the diet. These include 55% to 60% carbohydrates compared with 15% to 20% protein and 30% to 35% fat. These guidelines are appropriate to describe a general distribution of calories, but more specific guidelines are appropriate for athletes. Although research has not definitively described the most optimal macronutrient percentages, one might assume that athletes may need more carbohydrates than sedentary people.

The typical daily diet in the United States provides approximately 4 to 5 grams (g) of carbohydrate per kilogram (kg) of body weight. Carbohydrate recommendations for athletes range from 6 to 10 g kg^{-1} day^{-1}, with an average intake of 5 to 7 g/day for general training, increased to 7 to 10 g/day for those athletes training for endurance events, such as a triathlon or a marathon. Furthermore, a new area of training in the form of the ultramarathon may require as much as 11 g kg^{-1} day^{-1} or higher.

Using an absolute value such as 5 to 7 g kg^{-1} day^{-1} is a better method of determining what is best for an athlete as it takes into account body weight. For example, a more muscular athlete with a higher body weight who has a very intense training schedule may require more total energy with a lower amount of carbohydrates than an athlete with a lower body weight and less intense training regimen. This is often found to be the case in female athletes who may be trying to maintain a low body weight or body fat percentage. The bottom line is that each athlete's carbohydrate prescription is best determined individually, based on body weight, sport-specific considerations, energy balance, and adequacy of macronutrients (protein, carbohydrate, and fat) and micronutrients (vitamins and minerals).

Another important consideration for athletes is to consume enough calories. Research has shown that a low-calorie diet, even if it has adequate carbohydrates, may impair performance by lowering glycogen stores in both muscles and the liver. This applies to athletes who are also interested in weight loss and, thus, consume low-calorie diets. Low-energy diets may decrease muscle mass as well as impair the acid-base balance. However, if energy is increased and adequate carbohydrates are consumed, this damage may be reversed. It is also important for athletes to consider carbohydrate needs not only for the event but for training as well. Often, athletes pay more attention to the event, neglecting the importance of daily carbohydrate consistency. In summary, adequate energy and carbohydrates on a daily basis will help maintain muscle glycogen concentrations. Conversely, inadequate energy and carbohydrates during training may cause a gradual decrease in muscle glycogen content, impairing both training and competitive performance.

Carbohydrates are classified in several ways. Formerly, carbohydrates were referred to as either simple or complex. Simple carbohydrates are basic sugars that are single or one-unit sugars. They include glucose, fructose, and galactose. Disaccharides, or two-unit sugars, are two simple sugars linked together. They include sucrose (broken down into glucose and fructose), lactose (broken down into glucose and galactose), and maltose (broken down into two glucose units). Simple carbohydrates have very few nutrients and must be converted into glucose before the body can use the sugar as fuel. Simple sugars include foods such as honey, raw sugar, syrup, candy, jelly, and table sugar. Complex carbohydrates contain mostly glucose units that are joined together in compounds called *polysaccharides*. Complex carbohydrates include starch, fiber, and glycogen. They include basically any carbohydrate contained in whole foods.

Another classification of carbohydrates is called the *glycemic index* (GI). This is a more comprehensive explanation of the quality of carbohydrates. GI is a relative number that describes the potential of a food to raise the blood glucose level and subsequently the insulin level. Foods are compared with either white bread or pure glucose to obtain a number called the *GI*. In general, the higher the GI, the greater the potential of the food to raise the blood glucose level and thus be rapidly absorbed. Conversely, the lower the GI, the slower the rate of digestion and absorption of the carbohydrate. Foods are often classified into three categories—high, medium, and low GI. Examples of high-GI foods are bread, rice, potatoes, many breakfast cereals, and sports drinks. Moderate-GI foods include foods such as sucrose (as it is broken down into glucose and fructose), bananas, and oats. Low-GI foods include fructose, milk and many milk products, legumes, pasta (as it is made from higher-fiber wheat), and apples.

Not only does the GI reflect the effect of the food on blood glucose and insulin, but it also represents the form of the food, including the size of the carbohydrate grains (e.g., whole or refined grains); the degree of food processing; whether the food contains fructose and lactose (both of which have a low GI); the presence of fat or protein (both of which slow down the absorption of the carbohydrate); and the fiber content.

GI is often a consideration of sports nutrition. Some propose that low-GI foods are best taken before exercise to promote a sustained and slower absorption of carbohydrates, thus promoting more carbohydrate availability. Moderate- to high-GI foods may be recommended during exercise to ensure optimal muscle glycogen stores, as well as to enhance recovery after the exercise. GI may in fact be useful to help guide carbohydrate choices before and during events; however, further studies are warranted. Athletes would be wise not only to consider the GI but also to take into account the nutrient value, taste, cost, preparation, portability, and any gastrointestinal side effects of the food, such as gas, bloating, constipation, or loose stools.

Carbohydrates Before Exercise

Some research has shown that athletes should not consume high-glycemic carbohydrates before exercise. The reason for this is that these carbohydrates may lead to muscle glycogen depletion and even to hypoglycemia. However, other research has shown that this hypoglycemia may resolve in the first 30 minutes of exercise and does not impair performance. Basically, there is as yet no conclusive evidence to recommend that athletes should consume low-GI foods prior to exercise. However, if carbohydrate consumption is not possible during exercise, then a low-GI meal may give more sustained energy. Athletes should experiment with various foods to determine which foods are the most beneficial during training and competition. For athletes who have not eaten prior to aerobic exercise, eating or drinking a low- to moderate-GI food may be beneficial.

Athletes who have more intense training regimens as well as higher body weights may not be able to consume enough solid food to meet their daily caloric needs. In this case, a high-calorie sports beverage may be helpful. Liquid supplements with a high percentage of carbohydrate, as well as glucose polymers, may be helpful if an athlete has trouble meeting caloric needs with solid foods. These supplements are not only convenient but also have low fiber content, thus having less potential to cause gastrointestinal discomfort.

An important aspect of carbohydrates before exercise is the pre-exercise or pre-event meal. The pre-event meal does not provide immediate energy, but it does provide energy for exercise that lasts for 1 hour or longer. Many athletes neglect the pre-exercise meal. As liver glycogen stores may be reduced during sleep, the pre-exercise meal is important to ensure sustained aerobic exercise. It is best to consume carbohydrates 2 to 4 hours before exercise not only to help top off liver glycogen but also to ensure optimal blood glucose for sustained exercise.

There is considerable research on the ideal pre-exercise meal. When preparing this meal, it is important to take into account the total amount of carbohydrate as well as the type and timing of carbohydrate ingestion. Foods consumed right before exercise have the potential to divert blood from the muscles to the gastrointestinal tract. A good way to avoid gastrointestinal distress prior to exercise is to consume less carbohydrate just prior to exercise. Approximately 4 to 5 g/kg of body weight should be consumed 4 hours prior to exercise, whereas 1 g/kg is optimal in the last hour before exercise. This will help avoid any gastrointestinal side effects such as gas or bloating. An easy way to remember the timing of carbohydrate intake prior to exercise is to have 1 g/hour before exercise. Thus, 4 hours prior to exercise, consume 4 g/kg; 3 hours before, consume 3 g/kg; 2 hours, before consume 2 g/kg; and 1 hour before, consume 1 g/kg.

In terms of the type of pre-exercise carbohydrate, the food should be portable, palatable, carbohydrate rich, and easily digested. The GI may be helpful, but the effects of low-, medium-, and high-glycemic foods vary by individual. Thus, it is important for the athlete to experiment with the types of food that foster good performance and are well tolerated.

Carbohydrates During Exercise

Carbohydrates taken during exercise serve to maintain blood glucose stores at higher levels, thus increasing the use of blood glucose during a time when muscle glycogen stores are lower. This is very helpful not only in endurance sports, such as running, but also in sports such as tennis, basketball, soccer, and cycling, which require repeated periods of high-intensity, short-duration effort. During exercise, it is recommended that athletes consume 30 to 60 g of carbohydrates per hour.

This translates to 120 to 240 calories (cal; 1 cal = 4.18 joules) of carbohydrates per hour. This can be obtained from either solid or liquid foods, depending on the athlete's preference. The GI may make a difference, but research has not yet supported intake of any one type of carbohydrate during exercise. Again, it is up to the individual to determine what works best. Most athletes prefer medium- to high-glycemic foods, such as sports bars, cookies, or fruits such as bananas.

Energy bars are one of the most popular options for snacks during exercise. The best type of exercise bar is one that has more than 80% carbohydrate and less than 10% fat. Some protein in the bar is also helpful, as research shows that during exercise as much as 10% of the energy may come from protein stores in the body. Some athletes choose cookies or candy bars. However, the higher fat content of these foods may not be optimal for performance, as fat may slow down the absorption of the carbohydrates. The primary fuel used during exercise is carbohydrates, so it is best to choose a food that is mostly rich in carbohydrates. One other consideration is to consume fluid with the energy bar. A carbohydrate-rich diet and adequate hydration are the greatest ergogenic aids.

Some athletes prefer to consume liquid supplements during exercise. The typical liquid supplement contains between 4% and 8% carbohydrate. Therefore, if an athlete consumes a sports beverage that is 8% carbohydrate, 24 fluid ounces (oz; 1 fl oz 29.57 milliliters [ml]) consumed per hour will supply 57 g of carbohydrates. By comparison, sports gels provide an average of 25 g/hour, one banana provides 30 g, and an average sports bar provides 66 g. Thus, both liquid and solid foods rich in carbohydrates will supply adequate carbohydrates during exercise.

Fructose is another sugar that is used by some athletes during exercise. Fructose has a low GI as it is converted to glycogen primarily in the liver. However, most likely, it is not converted rapidly enough to blood glucose to support optimal performance during exercise. There also are potential gastrointestinal side effects with fructose, as it may have an osmotic effect in the gastrointestinal tract, where it draws in excess water, and may lead to cramping, bloating, and diarrhea. Some sports beverages contain more than one source of carbohydrate, such as glucose, sucrose, maltodextrins, and fructose. These types of sports beverages may actually enhance performance owing to the extra absorption of water.

Carbohydrates After Exercise

Carbohydrates should also be consumed after exercise. This is particularly important in restoring muscle glycogen stores to ensure optimal performance for consecutive exercise sessions. Athletes who train hard over a period of days or several times in 1 day, as well as those who compete in events that last more than 1 day, especially need to ensure that they have a recovery snack after each exercise session. This will help avoid the discouraging feeling of "hitting the wall" and not performing at one's best.

Research shows that consuming carbohydrates within 15 minutes of completing the event or practice will provide optimal muscle glycogen restoration. Exercise lasting more than 60 to 90 minutes requires 1.5 g of carbohydrates per kilogram of body weight immediately after exercise and another 1.5 to 2 g/kg 2 hours later. Research has shown that delaying the ingestion of carbohydrate by 1 to 2 hours may reduce muscle glycogen stores by more than 50%. In terms of the types of carbohydrate that promote optimal restoration of muscle glycogen, glucose and sucrose seem to be better than fructose.

Athletes need to experiment with foods to determine the best foods to consume after exercise. Many athletes prefer foods with a high GI. These foods include bread, potatoes, cereals, and sports drinks. Other athletes prefer a moderate-glycemic food, such as chocolate milk, a banana, or a tropical fruit such as dried mangoes. For those athletes who complain that they are not hungry after exercise and have trouble consuming food, liquids that are high in carbohydrates, such as a high-carbohydrate sports beverage, may be helpful. Another consideration after exercise is to restore hydration. This will be covered in a later section.

There is also research supporting that some protein consumed along with carbohydrates after exercise facilitates recovery. No conclusive data have been found that suggest that the addition of protein aids in restoring muscle glycogen. However, the addition of protein may enhance muscle growth and repair. When combined with proteins, carbohydrates may have a sparing effect on the protein, thus further enhancing muscle synthesis.

One final consideration about carbohydrates is their fiber content. Studies of populations suggest that adequate dietary fiber helps protect against heart disease, certain kinds of cancers, and diabetes. Fiber is often classified according to its solubility in water. Soluble fiber, or fiber that is soluble in water, creates a viscous material that helps promote satiety or the feeling of fullness after a meal, lowers blood cholesterol, and also slows down the absorption of blood glucose, providing longer-lasting energy. Examples of soluble fiber include citrus fruits, oats, barley, and legumes. Insoluble fiber does not dissolve in water and is found in high concentration in vegetables, cereals, and wheat. Insoluble fiber plays an important role in gastrointestinal health as it helps increase the bulk of the stools and thus promotes a faster transit time. As with all food, athletes are encouraged to experiment with amounts of dietary fiber that enhance their training and performance. In general, the amount of fiber recommended for adults is between 25 and 30 g/day.

Protein

Protein builds and repairs body tissue and forms the major component of enzymes, hormones, and antibodies. The dietary reference intake (DRI) for protein is 0.8 g kg^{-1} day^{-1}, which translates to 0.36 g $pound^{-1}$ (lb) day^{-1} (1 lb = 0.45 kg). This amount is established for individuals above 18 years of age and does not take into account the amount of physical activity. As with carbohydrates, protein supplies 4 cal/g. Fat provides more than twice the energy of carbohydrates or protein, providing 9 cal/g.

Research suggests that active individuals may require more than the DRI of protein to sustain their activity and to support optimal performance. Recently, the American College of Sports Medicine (ACSM), the American Dietetic Association (ADA), and the Dietitians of Canada (DC), all have agreed that active individuals have higher protein requirements. Their position statement recommends that protein consumed by endurance athletes should be 1.2 to 1.4 g kg^{-1} day^{-1} and that strength or resistance-trained athletes may need to consume up to 1.6 to 1.7 g kg^{-1} day^{-1}. Athletes may determine their daily protein needs by multiplying these figures by their weight in either kilograms or pounds.

To determine the amount of protein needed to meet daily requirements, the average amounts in foods are totaled. For example, in each cup of milk or yogurt, as well as in 1 oz of cheese, the average amount of protein is 8 g. Each ounce of meat, poultry, or fish has an average of 7 g of protein. Carbohydrates such as bread, rice, and pasta also contain protein. Each slice of bread, one half cup of pasta, or one third cup of rice has an average of 3 g of protein. Of note is that the average American diet contains about 100 g of protein per day, thus insufficient protein is rarely a problem.

One of the reasons why athletes may require more protein than sedentary individuals is that it contributes 5% to 15% of the fuel required for exercise. The amount of protein used for fuel increases as the amount of muscle glycogen decreases. Thus, endurance athletes may use greater amounts of protein. Second, exercise may cause muscle breakdown, which increases the amount of protein needed, as protein is the only macronutrient used to build and repair muscles. Finally, endurance athletes seem to lose a small amount of protein in the urine, whereas protein is typically not lost in the urine of a healthy person who engages in little to no exercise.

Protein requirements remain somewhat controversial among athletes. Many falsely believe that they need more protein than they actually do. This is a common misconception and may lead to an athlete consuming more protein than is necessary. The key concept is that an athlete needs adequate protein and, most important, enough protein to spare or make available for growth and muscle repair. This ensures that the protein is not pulled into the pool of total calories and is used just to keep the athlete functioning, instead of functioning optimally.

Excess protein may actually be detrimental to optimal performance. When there is excess protein and it is burned as fuel, the nitrogen must be removed from the protein and excreted. When the excretion of nitrogen is increased, the amount of water lost in the urine also increases. Thus, the use of protein as fuel not only diverts protein from its main functions of cell growth and repair but also increases the risk of dehydration. High-protein diets have also been shown to increase the amount of calcium in the urine. This is a particular problem for athletes and for bone health. Finally, a high-protein diet may also indicate a high-fat diet. This could increase the risk of certain diseases, such as cardiovascular disease. In summary, adequate protein, and not excessive protein, should be a guiding nutrition principle for athletes.

Some athletes may actually require more protein. These include athletes who are still growing, especially those who have not had their pubertal growth spurt. Other athletes who may require more protein are those who are restricting food intake to achieve a desirable weight. Furthermore, athletes who restrict protein for religious or cultural purposes or those who practice some form of vegetarianism may need to monitor food choices carefully to ensure that they consume enough protein to support optimal training and performance.

Protein is found in both animal and plant sources. Animal protein includes meat, poultry, fish, dairy products, and eggs. Plant sources of protein include legumes, nuts, seeds, grains, and vegetables. Formerly, it was thought that vegetarians needed to combine proteins at each meal and snack to ensure an optimal balance of amino acids. These regulations have been relaxed, and the guidelines are to consume enough total protein in a day to meet the basic needs, as well as any additional protein needed for growth and optimal training and performance.

Athletes often consider using protein supplements to enhance their performance. Not only are protein supplements costly, but for the most part, they are unnecessary. As stated above, although athletes may need slightly more protein than nonathletes, these additional requirements can be easily met through increased calorie intake in food. It is important to remember that muscle strength, shape, and size come from genetics and athletic training and not from protein supplements.

Fat

Fat is a major energy source that not only helps meet daily energy needs but also supplies energy when other sources of readily available energy, such as glucose, are depleted. The extent to which fat supplies energy depends on the duration and intensity of the exercise. Fatty acid oxidation during endurance exercise provides more energy than when carbohydrates are oxidized. However, fatty acid oxidation also requires more oxygen and, thus, puts more stress on an athlete's cardiovascular system.

Fat also helps maintain body temperature and provides insulation for body organs. It lines brain and nerve cells and, thus, is an important part of nervous system and brain functioning. Fat is involved in the regulation and action of insulin, a food-related hormone or control substance that regulates the formation and storage of glucose as fat. Fat is also the vehicle for the absorption of fat-soluble vitamins such as vitamin D (for bone health), vitamin A (for optimal eye function), vitamin E (for antioxidant function), and vitamin K (for normal blood clotting). Dietary fat contributes to the taste of foods, as well as helps promote satiety, or the feeling of fullness after eating.

The total amount of fat necessary in a diet has not been precisely described. Rather, based on the role that excess dietary fat may have in chronic diseases such as heart disease, a value called the acceptable macronutrient distribution range (AMDR) has been established instead. There is a range for all macronutrients (protein, carbohydrates, and fat) that not only considers reducing the risk of chronic diseases but also ensures adequate intake of the nutrients contained within each macronutrient group. The AMDR for total dietary fat is set at 20% to 35% of the total calories consumed per day.

The amount of fat in an athlete's diet will vary depending on the amount of total calories consumed, the type of sport, and the level of training. The overall guideline is that, as with all macronutrients, dietary fat should be individualized, taking into account an athlete's growth stage, nutrition needs, taste preference, physical activity level, energy expenditure, and sport-specific considerations. Runners, cyclists, and other endurance athletes may require more fat so that they have enough energy when stores of glycogen are low. Athletes in appearance sports such as gymnastics and figure skating can have much lower intakes of fat and may even consume well below the recommended range, particularly if they are trying to achieve lower body fat levels.

Low-fat diets, especially those with fat content less than 20% of the total calories, are not necessarily optimal. Athletes who are trying to lower body weight or body fat often tend to increase the intake of carbohydrate at the expense of both fat and protein. For some athletes, especially those who are still growing, a low-fat diet may not provide sufficient energy to meet the needs of both growth and training. Athletes are wise to consider not only the short-term goal of optimal training and performance but also the midterm goal of growth and development and finally the long-term goal of a healthy adulthood.

Another unhealthy consequence of a low-fat diet is that deficiencies of both fat-soluble vitamins and essential fatty acids (e.g., the omega-3 fatty acids) may develop. Furthermore, athletes following low-fat diets may also avoid dairy products, meat, fish, poultry, and eggs, leading to deficiencies of calcium, iron, and zinc. Female athletes may compromise estrogen production with accompanying menstrual dysfunction. Male levels of testosterone may also be compromised with low-fat diets. Thus, low-fat diets in both sexes may compromise not only reproductive function but also training and performance.

The type of fat consumed is an important consideration in a healthful diet. Athletes should watch their consumption of saturated fat by consuming both low-fat dairy products and lean meats. Trans fats (hydrogenated or partially hydrogenated oils) should be eliminated. The emphasis should be on heart-healthful monounsaturated fats, found in foods such as nuts, seeds, avocados, and oils such as olive oil. Polyunsaturated fats are also important as they supply essential fats that are not made in the body and hence must be consumed in the diet instead. These fats include the omega-3 fatty acids.

The omega-3 fatty acids are one type of polyunsaturated fat that have many positive benefits for athletes. These benefits include improved delivery of oxygen and nutrients, increased aerobic metabolism, reduced inflammation of fatigued muscles, and possible prevention of tissue inflammation. Athletes would be wise to consider adding omega-3 fats to their diets. A good dietary practice is to include two, 4- to 5-ounce (oz; 1 oz = 28.35 grams) servings of a cold-water fish each week. Examples of cold-water fish include salmon, albacore tuna, Atlantic herring, and sardine.

One type of fat called medium-chain triglycerides (MCT) is hypothesized to have beneficial attributes for athletes. MCT oil is more directly absorbed than other fats and is rapidly converted into the component parts of fats—fatty acids and glycerol. There is also some evidence to suggest that MCT oil may help mobilize fats from storage and increase the rate at which these fats are burned. MCT oil may also offer benefits for athletes who are trying to maintain lower body fat levels, as the metabolism of these fats may increase overall metabolism in the short term. It should be noted that MCT oil consumed in amounts greater than 30 g (270 calories) may cause gastrointestinal distress such as cramping and diarrhea.

Vitamins and Minerals

Along with the three large nutrients or macronutrients, the micronutrients (including vitamins and minerals) also play an important role in sports nutrition. Vitamins and minerals are necessary for the proper functioning of all body tissues. They are essential for the release of energy from macronutrients by serving as enzymes and cofactors for metabolism. They are called micro- or small nutrients, as although each vitamin and mineral has an important role in maintaining normal cell and body function, they are needed in only small amounts. This is an important consideration for athletes as many think that they need to take vitamins and minerals in mega doses to achieve optimal performance.

The government agency called the Food and Nutrition Board publishes the Recommended Daily Intake (RDI), which includes the recommended daily allowance (RDA) for vitamins and minerals. The RDA is the amount of a vitamin or mineral that will protect a person from certain chronic illnesses or diseases associated with deficiency states of vitamins or minerals. As the RDA is set using sedentary adults as the base, it is often hypothesized that athletes may need more as they are active.

Thiamin, riboflavin, and niacin are B vitamins that are needed to produce energy from food. Carbohydrate and protein foods are excellent sources of these vitamins. Adequate amounts of these vitamins will be obtained from a diet with adequate calories. However, one exception is that some women athletes may lack riboflavin as they do not consume milk and milk products. Milk products not only increase the riboflavin level but also provide protein and calcium. In terms of fat-soluble vitamins, including vitamins A, D, E, and K, the body stores excess of these vitamins. Thus, excessive amounts of these vitamins, especially vitamin D, may have toxic effects.

Minerals play an important role in athletic performance. Endurance or heavy exercise may affect the body's supply of sodium, potassium, iron, and calcium. Sodium lost through sweating may be replenished by eating normally following a competition. Consuming potassium-rich foods, such as oranges, bananas, and potatoes, will supply the necessary potassium. Iron carries oxygen and is another important mineral for athletes. Some athletes, especially women athletes, may have inadequate supplies of iron. Iron supplements may be prescribed by a physician if laboratory tests indicate an iron deficiency. Calcium is another important nutrient, not just for athletes but for bone health in everyone. Women athletes who avoid consuming dairy products may need supplementation to avoid calcium loss from bones. Dairy products, especially low-fat choices, are considered good sources of calcium.

Many athletes take a low-dose multivitamin and mineral supplement to give them the mental satisfaction that they are getting enough of each vitamin and mineral. Research shows that in low doses, vitamin and mineral supplements pose no risk. Conversely, there may be individuals who require more of certain vitamins or minerals. These individuals include those with monotonous diets, those who follow some type of a vegetarian diet, or those with conditions such as food allergies, lactose intolerance, inflammatory bowel disease, celiac disease, or diabetes. In these cases, it is best to consult with a registered dietitian to determine the best supplementation regimen. The bottom line on supplementation is that athletes who consume enough total calories, in a varied diet, to support regular daily activities of living, as well as sport-specific increased caloric needs, will most likely have sufficient vitamins and minerals for optimal performance.

Hydration

Proper hydration is essential to sports nutrition. Athletes should make a conscious effort to drink fluids throughout the day. Fluids include not only the free water in foods (e.g., fruits and vegetables that have a high water content) but also plain water, juice, sports beverages, decaffeinated beverages, and soups. Many athletes prefer the taste of sports drinks to water. However, a sports drink is really no better than water, unless exercise lasts for more than 90 minutes or occurs in hot weather. The additional carbohydrates and electrolytes may improve performance in these conditions, but otherwise the body will do just as well with water. Drinking carbonated drinks or juice is not recommended as they may cause cramping, bloating, or diarrhea during training or competition.

A simple way to gauge fluid needs is to weigh before and after a workout. A minimal weight loss usually means that there is adequate fluid and fluid replacement. A weight loss of more than 2 pounds probably indicates inadequate fluid intake and possibly dehydration. Conversely, gaining weight during exercise may be a sign of excessive drinking or overhydration, indicating the need to reduce the amount of fluid during exercise.

There is individual variation in how much an athlete should drink. Fluid needs depend on the individual's age, size, and level of physical activity, and the environmental temperature. Athletes should drink before, during, and after exercise. In general, most athletes need one to two cups prior to exercise and half to one cup every 15 to 20 minutes during exercise. Thirst is not a reliable indication of the need for hydration and may actually indicate dehydration. Therefore, it is important for an athlete to drink before thirst occurs to maintain proper hydration.

Finally, if dehydration does occur during a period of strenuous exercise, it may take 1 to 2 days to fully recover and replace sweat losses. If this does happen, the athlete should drink often during this time and monitor hydration by checking the urine for its color. If the urine is straw colored, then the athlete is most likely properly hydrated. However, if it is dark, the urine may still be concentrated with metabolic waste. One exception to this is if a multivitamin is consumed, as it may cause urine to be yellow. In this case, hydration should be monitored by the volume of urine produced.

In summary, proper nutrition and hydration not only influence growth but also lead to optimal training and performance. Athletes are urged to consider constructing their diets carefully. Professional help from a registered dietitian is advised for all serious athletes.

Jan Pauline Hangen

See also Calcium in the Athlete's Diet; Carbohydrates in Athlete's Diet; Dietary Supplements and Vitamins; Fat in the Athlete's Diet; Postgame Meal; Pregame Meal; Protein in the Athlete's Diet; Salt in the Athlete's Diet; Sports Drinks; Vegetarianism and Exercise; Weight Gain for Sports; Weight Loss for Sports

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O

Obesity

Obesity is a condition that can have wide-ranging effects on the physical, mental, and economic health of an individual. Contributors to obesity include an individual's environment and behavior (e.g., consumption of energy-dense foods and decreased physical activity), genetics, and sociocultural networks. Obesity can cause social stigma and create strong emotional reactions, such as anger, fear, and depression. It also can affect the economic health of societies.

The Epidemic of Obesity

After a gradual but sustained increase, the prevalence of obesity in adults in the United States has reached a plateau, with about one third of adults currently meeting the body mass index (BMI) criteria for obesity, according to data from the November 2007 National Health and Nutrition Examination Surveys. The prevalence of obesity in U.S. children, although it has tripled over the past 30 years, has also shown signs of reaching a plateau. Unfortunately, the global prevalence of obesity is steadily increasing, multiplying threefold in the past 20 years. Ten percent of children worldwide are considered obese. An additional review of the epidemiology of obesity demonstrates an overall increased incidence in those affected by poverty.

What Is Obesity?

The current definition of obesity, for adults and children, centers on a person's BMI, the ratio of one's weight (in kilograms [kg]) to the square of one's height (in meters [m]). The metric formula for BMI is as follows: BMI = kg/m^2. Although it is not a direct measure of adiposity, BMI has been shown to correlate with body fat. In adults, a person is overweight when his or her BMI reaches the range of 25 to 29.9 kg/m^2; he or she is obese when his or her BMI is ≥30 kg/m^2. As natural fluctuations of the appropriate ratio of weight to height occur in growing children, the use of BMI for children greater than 2 years of age is based on the percentile of BMI for gender and age from the 2000 Centers for Disease Control growth charts. Obesity in children under the age of 2 is determined by simple weight-for-height values. BMI weight categories in children are defined as follows:

- Obesity: ≥95th percentile or BMI ≥30kg/m^2 (whichever number is lower)
- Overweight: 85th to 94th percentile
- Healthy weight: 5th to 84th percentile
- Underweight: <5th percentile

The 85th and 95th percentiles were chosen to avoid the overdiagnosis of obesity in muscular teens and the underdiagnosis in lower-BMI teens with higher percentages of body fat. With the increasing prevalence of severely obese children, new recommendations are being proposed to add an additional percentile category of ≥99th percentile, as those children will have significantly increased risk of the associated medical complications of obesity.

The Etiologies of Obesity

At its simplest, weight gain relates to an alteration of the balance between energy intake and energy expenditure in favor of intake. Today, increased intake can take many forms, including increased consumption of sugary drinks, increased portion sizes for meals and snacks, and increased restaurant eating. Energy expenditure has also fallen due to decreased physical activity in schools, decreased routine daily physical activity (e.g., walking to school/work from home), and a greater prevalence of automatic gadgets (e.g., escalators, elevators).

Other related causes of obesity include psychosocial cues, genetics, and the gastrointestinal system. Socially, people are more likely to be obese if a close friend or family member is also obese. In the realm of genetics, twin studies of the past have demonstrated a genetic basis for obesity. In addition, recent research suggests that specific genes may play at least a small role in the tendency toward obesity—for example, genes affecting appetite, satiety, or fat absorption. However, the combination of multiple "obesity genes" and/or environment can augment or lessen the effects of one gene. New research has also found a different composition of intestinal flora (bacteria) in lean versus obese mice and humans, the exact effect of which is currently unknown. Other surveys have demonstrated that sports can lead to obesity as well. The extreme sports fan has a higher BMI than the average spectator. He or she tends to be more sedentary, and while sitting and watching the event, he or she will eat more, have higher-fat foods, and drink more alcohol.

The Effects of Obesity

Obesity affects the physical, mental, and psychosocial health of an individual. People diagnosed with obesity have a shorter life span and are at increased risk for diabetes, coronary heart disease, hypertension, arthritis, certain cancers, and obstructive sleep apnea. They are more likely to experience depression and anxiety than the nonobese. People who are diagnosed as obese have also been subjected to social stigmatization. Obese children can develop general musculoskeletal disorders, such as shin splints and stress fractures, and painful joint conditions, such as *Blount disease,* an abnormal and painful bowing of the leg, or *slipped capital femoral epiphysis,* a shift of the growing part of the femur, resulting in hip pain and decreased motion. They are also at higher risk for heat illness than their same-age, normal-weight counterparts. They also can develop many of the adverse physiologic consequences of obesity listed above.

Unfortunately, obesity has socioeconomic effects as well. Obesity can lead to increased levels of disability, decreased ability to perform activities of daily living, and decreased functional capacity. Obese individuals also experience increased health care utilization and increased overall health care costs.

Prevention and Management of Obesity

It is often said that difficult things become more difficult when they are performed alone. For children, particularly, obesity prevention and management should involve the entire family. The school and the community should also play a role in overcoming obesity (e.g., adequate physical education and recess time, healthy nutrition programs, safe parks and recreation centers, mandates for healthy food grocery stores).

As with any medical condition, preventing the disease from occurring should be the primary goal. This is especially true of obesity, as managing obesity can be costly in time, energy, and money. Prevention includes frequent risk assessments (medical and behavioral) at routine doctor's visits and frequent praise of current healthy behaviors. It is important to identify less healthy behaviors and other barriers to achieving a healthy weight, such as an individual's cultural beliefs and community infrastructure and safety.

Once a person is diagnosed with obesity, the next step is an assessment of his or her stage of readiness to change, his or her strengths to make the change, any barriers preventing the change, and the individual's goals to direct change.

Depending on the obese individual's readiness to change, the management of his or her obesity can follow four general courses, listed in increasing levels of treatment risk and effectiveness:

(1) acceptance of the current weight, (2) losing weight with behavior modification (i.e., diet and exercise), (3) losing weight with medications, and (4) losing weight with surgery. Increased consideration is being given to a combination of these therapies.

The simplest description of a diet for weight loss is one of reduced caloric consumption. Although the method of attaining this reduced consumption can vary from low fat to low carbohydrate to high protein, important considerations when determining an appropriate weight loss diet include long-term maintenance and the direct health benefits of the diet itself (e.g., a low-fat diet to help lower one's cholesterol).

When it comes to adding exercise to an individual's weight loss routine, in general, a little is good, more is better. Exercise has been shown to decrease weight as well as all-cause mortality (even when still obese but fit). The way in which an individual increases his or her activity can vary; however, a successful approach to increase physical activity in adults is by walking and using a pedometer. Recent studies support the use of team sports in treating obesity in children. Not only do obese children benefit from the added physical activity, but they also experience a boost in self-esteem, sports interest, and athletic capabilities.

Slow progress has been made in using medications to aid weight loss, due to difficulty translating successful animal research to humans. Two approved drugs operate at different points in the obesity cascade. Orlistat, approved by the Food and Drug Administration (FDA) for ages 12 and older, works by causing malabsorption of fat in the intestines. Sibutramine, which affects brain chemistry, is an FDA-approved drug for weight loss in individuals 16 years of age or older when combined with diet and exercise.

For those who have been unsuccessful in losing weight with behavior modification and medication, surgery presents an additional option. Various successful surgical methods are currently performed, the selection of which is patient specific. Weight loss, or bariatric, surgery has been shown to decrease all-cause mortality, as well as mortality from diabetes, heart disease, and cancer, related to obesity. With the benefits of surgery come risks as well. One study noted a slightly higher rate of accidents and suicide in the surgery versus nonsurgery group. Additionally, some general complications may occur with any surgical procedure and may include anesthetic complications, infection, and bleeding. Bariatric surgery in children is restricted and must meet certain criteria related to BMI (≥40 kg/m^2 with medical concerns or ≥50 kg/m^2), their complete physical maturity, their cognitive and emotional maturity levels, and their previous weight loss efforts.

Nailah Coleman

See also Benefits of Exercise and Sports; Conditioning; Exercise Physiology; Exercise Programs; Gender and Age Differences in Response to Training; Mental Health Benefits of Sports and Exercise; Pediatric Obesity, Sports, and Exercise; Weight Loss for Sports

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Olecranon Stress Injury

Stress fractures of the olecranon are relatively uncommon sources of posterior elbow pain. They have been reported primarily in baseball players, particularly pitchers, and also in gymnasts, weight lifters, and javelin throwers. They must be considered in the differential diagnosis of posterior elbow pain with activity.

Anatomy

The olecranon is the most proximal portion of the ulna bone. It helps the elbow to flex and extend, and when the olecranon articulates with the olecranon fossa, it helps keep the elbow locked in extension. The lower portion of the triceps attaches to the olecranon, allowing for elbow extension.

The injury is considered to be due to either repetitive stressful trauma to the olecranon as it strikes into the olecranon fossa or tension from the triceps tendon on the olecranon. In the skeletally immature athlete, the repeated stress may cause widening of the olecranon epiphysis, resulting in a nonunion or delayed closure of the physis.

Signs and Symptoms

The athlete will present with pain in the posterior elbow, typically posterior lateral. Pain will be most frequent with activity but may occur with rest or direct pressure on the posterior elbow. In throwers, pain is often reported during the late acceleration and deceleration phases of throwing. Often, periods of rest may have been attempted, with return of symptoms soon after resumption of activity.

Physical Examination

On examination, pain will usually be felt on palpation of the olecranon around the posterior, and often posterior, lateral elbow. Soft tissue swelling may be present. Forced extension of the elbow may reproduce the pain. Pain may also be present with active resistance of the triceps. Limited extension of the elbow may be present but is not a unique finding of this condition.

Imaging Studies

Plain-film X-rays are the first-line imaging choice in evaluating for olecranon stress fractures. In adolescent athletes, a comparison with the lateral radiograph of the unaffected elbow may be helpful to see if the olecranon physis has fused. If the physis has fused on the unaffected side, then the likelihood of a delayed fusion or an olecranon stress fracture is higher than if a fracture or persistent physis is visualized on the affected side.

Further imaging with a bone scan, a computerized tomography (CT) scan, or a magnetic resonance imaging (MRI) scan may be helpful in confirming the diagnosis. An MRI scan may also identify other conditions contributing to the problem, such as insufficiency of the ulnar collateral ligament.

Treatment

Both surgical and nonsurgical options have been reported to help treat this condition. Nonsurgical treatment includes complete rest from all activities that produce pain. Generally, the time taken to heal may be 6 months or longer. To help facilitate healing, electrical bone stimulation may be considered. But with this stimulation, there is a potential risk of this stress fracture becoming a painful nonunion. Because of this risk and the uncertainty of nonsurgical treatment, many high-level athletes are encouraged to undergo surgical fixation with open reduction and internal fixation of the stress fracture. Arthroscopy of the elbow is often undertaken at the time of surgery to address any coexisting conditions in the elbow.

Mark E. Halstead

See also Baseball, Injuries in; Elbow and Forearm Injuries; Gymnastics, Injuries in; Stress Fractures

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Operating Room Equipment and Environment

Sports injuries are frequently minor and heal without much intervention. Unfortunately, many other types of sports injuries cannot heal without surgery. For this reason, it is useful to understand the surgical environment and the equipment used in the operating room.

The concept of the ideal operating room environment and equipment means different things to different people. The patient's concept of the ideal operating room equipment and environment is different from the surgeon's concept. In fact, the patient, the surgeon, the anesthesiologist, the nursing staff, the hospital administration, and the insurance company all have different concepts about what constitutes the ideal operating room and the equipment in that room.

Shared Goals

Despite having different needs and desires at many levels, all groups share three basic goals. First and foremost is patient safety. Many, if not most, of the rules regarding operating rooms involve patient safety. The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) and the Accreditation Association for Ambulatory Health Care (AAAHC) mandate many rules in and around the operating room to ensure patient safety. If the hospital or surgery center does not meet JCAHO or AAAHC guidelines, it loses its accreditation and is unable to perform operations until the shortcomings are corrected. Hospitals spend months getting ready for these inspections, ensuring that everyone knows and follows the rules. If, during such an inspection, someone does not know where to find a fire extinguisher, for example, the hospital is cited.

The second shared goal is optimal surgical results. This means minimizing complications such as infection and maximizing outcomes. While the nursing and anesthesia staff cannot do much to improve surgical techniques, they can continuously help decrease infections and pain and can help create an environment in which the surgeon can better concentrate on the operation. Administration tries to attract the most qualified doctors, and insurance companies help by rewarding excellence with incentives called "Best Practices."

The third shared goal is making the surgical environment and experience pleasant. When everyone works in a pleasant atmosphere, the outcomes will be better. Less anxious patients require lesser anesthesia and have fewer complications. No one can work at his or her best in a hostile environment.

If these three are the only variables to be considered, all operating rooms would have a perfect environment with perfect equipment. Unfortunately, other variables interfere with the ability to achieve perfection.

Patient's Perspective

For the patient, the environment starts with easy and free parking at the center. If the hospital provides hassle-free check-in and soothing music and décor in all patient areas, the patient's pain and anxiety are minimized. The patient expects state-of-the-art anesthesia and surgical equipment that is perfectly maintained. The patient wants a perfect operation, a nausea-free wake-up, no pain, and an easy transition back home with full directions regarding postoperative concerns. The patient also desires to have little or no out-of-pocket expenses associated with the operation.

Nurses and Staff Members' Perspective

Nurses and other staff members expect the patient to be well-informed about the operation, relaxed, and cooperative. They hope the doctors are on schedule and pleasant to work with. All paperwork needs to be perfect, and the patient should be protected from harm. After surgery, the nursing staff want the patient to be comfortable, to awaken safely, and to get full information before leaving the center. When nursing staff are efficient and get things done quickly, they do not want to be taken advantage of by being given additional work to do.

Surgeon's Perspective

The surgeon wants a relaxed, happy patient prior to surgery. He or she wants the operating room ready for surgery, with well-maintained, state-of-the-art equipment. All associated personnel should be focused on the operation and not get distracted by any other activities around. The surgeon wants perfect results, no complications, to stay on schedule, and to maximize efficiency.

Anesthesiologist's Perspective

Patient safety comes first, and the schedule may have to be modified if anesthesia takes longer than anticipated. First-rate anesthesia gear is desired, and it must be perfectly maintained. Anxious patients are more difficult to anesthetize, and so a happy, relaxed patient is desired. During the operation, the anesthesiologist wants a surgeon who is calm and efficient. In the recovery area, the anesthesiologist wants the nurses to be first-rate and to be able to respond to any patient's need.

Hospital Administrator's Perspective

Hospital administrators want safe, happy, well-prepared patients, and at the same time the administration needs to be financially prudent. Some patient amenities, such as parking, may not be good. The amenities in the hospital might not be ideal. Surgical equipment and anesthesia gear will be on a budget as well. The administrators have to walk a fine line trying to optimize outcomes while minimizing expenses.

Insurance Company's Perspective

Insurance companies want maximum care for minimal expense. Toward that end, they have forced patients to consult surgeons who have agreed to operate for lower fees. Likewise they have insisted that their members get their surgeries done at centers that have negotiated lower fees. When medical professionals and surgery centers accept low fees from insurance companies, they must work extra hard to keep their expenses down. The lower the fees, the more difficult it is to maintain the highest quality in the surgery center and hence the operating room equipment.

A Typical Knee Operation

The following example of a common sports medicine operation can demonstrate how equipment is used for surgery. A patient has a torn meniscus (spacer cartilage in the knee) and is scheduled for arthroscopic partial removal

Typical arthroscopic equipment for sports medicine surgery. Gear includes high-definition video camera, telescope, light source and fiberoptic cable, recording device, suction shaver to remove tissue, sterile fluid supply, suction drainage, and several hand tools.

Source: Peter G. Gerbino, M.D.

The hand tools include a probe to "feel" tissues and several instruments with tips that grasp, cut, punch, and otherwise handle various tissues. Another instrument frequently used is an electrocautery. This device uses radiofrequency current to heat tissues for removing, sealing, or shrinking those tissues. Special devices for sewing tissue, placing anchors in bone, creating waterproof gateways into the joint, and other unique functions are used as necessary.

Source: Peter G. Gerbino, M.D.

of the damaged tissue. Arthroscopy is a modern technique of doing most or all of an operation through tiny holes. Many, if not most, sports medicine operations are performed arthroscopically. These operations are done on the shoulder, elbow, wrist, hip, knee, ankle, and foot. Equipment includes a tiny, high-definition video camera, a telescope, a light source, a monitor, recording devices, and several hand tools. A typical equipment setup for arthroscopic surgery is shown at the top of page 1000.

The history and physical examination were done several days earlier at the surgeon's office. All paperwork (digital preferred) has been done, and the surgery center awaits the patient's arrival.

The patient arrives 1 hour prior to surgery, and the administrative and nursing paperwork is evaluated and processed. Nursing staff get the patient out of street clothes and record the information needed for administering medicines and ensuring a safe operation. The anesthesiologist meets the patient and discusses anesthesia options.

The surgeon arrives, signs his or her initials on the correct knee, and discusses any of the patient's or family's last-minute concerns. The surgeon ensures that all equipment is ready and functional.

In the operation room, the nurse transfers the patient to the operating table, and the anesthesiologist gets the patient off to sleep or uses other types of anesthesia to ensure a painfree operation. At this time, the anesthesiologist will typically give the patient an intravenous antibiotic to help decrease the risk of infection.

The surgeon positions the patient for knee arthroscopy and "scrubs in" (washes hands and puts on a sterile gown and gloves).

A ballet of sorts begins, with the anesthesiologist, surgeon, scrub nurse or tech, and circulating nurse doing their jobs and assisting one another. For meniscectomy, the arthroscope is inserted into the joint, and tiny instruments are passed through a 0.25-inch hole to repair or remove the damaged tissue. The surgeon's skill comes into play here, since identifying the problem, choosing the right tools for the job, and performing the actual meniscus repair or resection all depend on training and ability.

When the operation is done, dressings are applied, and the patient is awakened and taken to the postanesthesia recovery unit (PARU). This is frequently referred to as the recovery room. Here, the patient is supported until fully awake and ready to leave. Instructions on wound care and pain management are given prior to discharge.

Conclusion

The operating room is not simply a place where a surgeon fixes an injured athlete. There are many personnel and needs that must be considered. Everyone wants a safe, happy patient with an excellent result, but costs and incentives must be factored into the equation. The ideal operating room equipment and environment maximize safety, comfort, and excellent results while being mindful of fiscal and personnel costs.

Peter G. Gerbino

See also Back Injuries, Surgery for; Elbow and Forearm Injuries, Surgery for; Foot and Ankle Injuries, Surgery for; Hand and Finger Injuries, Surgery for; Hip, Pelvis, and Groin Injuries, Surgery for; Knee Injuries, Surgery for; Lower Leg Injuries, Surgery for; Shoulder Injuries, Surgery for; Sports Injuries, Surgery for

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The Joint Commission: http://www.jointcommission.org

Organ Injuries

Traumatic injuries, including organ injuries, occur mainly in contact sports where the players often suffer from blunt trauma, ranging from minor contusions to surgical emergencies. Most organ injuries, defined as "harm" or "damage" done or sustained to an organ, occur in sports that involve repeated collision with players or objects, such as football and rugby. Commonly encountered organ injuries are superficial and can be effectively treated, but some are more serious and can result in lifelong disability and even death.

Incidence

Statistics show that of all abdominal injuries being reported in the United States, 10% are sports related. Liver and spleen are the most commonly injured organs, making up one third of all abdominal injuries. Twenty-one percent of traumatic brain injuries (TBIs) are attributed to sports. Lung trauma is one of the major manifestations of thoracic injury. In the genitourinary system, kidneys are the most commonly affected viscera, mainly in children, and account for 2% to 28% of the cases of sports injury. Genital injuries are more common in males.

Following is a brief account of the most commonly injured organs.

Spleen

The spleen is a soft, highly vascular, lymphatic organ that lies along the axis of the 10th rib, under the diaphragm, lateral to the stomach in the left upper quadrant (LUQ) of the abdomen. It is enclosed by a tough, fibrous capsule.

Although it is protected by the rib cage, the spleen is the most frequently injured organ in all age-groups. Increase in size (splenomegaly) is a major risk factor, which occurs in cases of infectious mononucleosis, sickle cell anemia, and immune system disorders such as lymphomas. Any blunt trauma that affects the LUQ directly or a rib fracture can result, secondarily, in spleen injury.

Types of Injuries

Mild Splenic Subcapsular Hematoma. Hematomas are a collection of blood due to internal bleeding as in blunt trauma. They occur in small patches on and around the spleen. The bleeding is limited as the capsule is not ruptured.

Splenic Contusions. Also known as bruising, contusions are tissue injuries in which capillaries are ruptured and result in blood accumulation. Bleeding is on a larger area.

Splenic Lacerations (Tears). Laceration is the most common splenic injury. Profuse bleeding occurs due to its rich blood supply.

Diagnosis

A computerized axial tomography (CAT) scan is performed to help in diagnosis.

Treatment

Patient monitoring is required with maintenance of an intravenous (IV) fluid line. Splenectomy is often done if the noninvasive treatment fails. However, it is not preferred in children as it leads to greater risk of bacterial infections.

Liver

The liver is the largest solid organ of the body, lying in the right upper quadrant (RUQ) of the abdomen, extending up to the midregion. It is one of the intraperitoneal organs (the peritoneum is a membrane lining the abdominal cavity and covers most of the organs). Being a massive organ with a thin tissue capsule and a relatively fixed position in relation to the spine makes the liver the most frequently injured organ. Biliary tract injury is uncommon.

Blunt trauma injuries to the liver can occur by direct impact on the RUQ or upper midabdomen, a high-velocity impact on the right side of the body, crush injuries against the spine or ribs, or bursting of the liver capsule at its attachments.

Types of Injuries

Liver Contusion. Contusions occur as a result of direct impact on the abdomen during sports such as motorbike racing, skiing, soccer, and rugby.

Liver Laceration. Lacerations are cuts to the liver. As it is a highly vascularized organ, athletes with a lacerated liver can develop symptoms of shock rapidly due to profuse bleeding. Javelin throw, rugby, and football account mostly for this injury.

Clinical Findings

Extreme Tenderness Over the RUQ. Due to impact collision, fractures of the seventh to ninth ribs can also cause liver lacerations. Peritoneal irritation, which is characterized by pain on pressing the site and releasing it (rebound tenderness), is seen after 2 hours of injury due to accumulation of blood.

Diagnosis

Diagnosis is based on palpation for a stable player. Ultrasound and CAT scan are the most reliable methods for accuracy of diagnosis. Peritoneal lavage can be done to assess if there is any blood in the cavity. The extent of damage can be evaluated through liver enzyme tests.

Treatment

Contusions are cleared by the body's own healing mechanism. Rest is vital, along with maintenance of an IV fluid line. Lacerations also heal with time unless they are large, in which case laparotomy (a surgical procedure involving incision on the abdominal wall to gain entry into the cavity) is done.

Return to Sports

It depends on the clearance of hepatic injury, as shown by various imaging techniques.

Kidney

The kidneys are located behind the peritoneal cavity (retroperitoneal) bilaterally on the back of the body and are protected by the lower ribs and musculature.

Renal injuries account for 65% of the genitourinary injuries. They occur mostly in American football, hockey, and the martial arts. In children, cycling accounts for 24% of the renal injuries, whereas team sports account for only 5%.

Types of Injury

The different types of renal injury are renal contusion, small parenchyma renal hematomas, renal parenchyma laceration, and injury to the vascular pedicle.

Clinical Findings

There is flank pain with gross or microscopic hematuria (blood in the urine).

Diagnosis

Excretory urogram is advised. Patient can also be evaluated through a computed tomography (CT) scan.

Treatment

Minor injuries require bed rest. Immediate surgical intervention is done for hemodynamically unstable athletes.

Brain

The human brain is situated inside the skull, within the cranial cavity. The protective layers of the brain from outside inward are the scalp, skull, meninges (three membranes: dura mater, arachnoid mater, and pia mater) and ventricles (expansion of the central canal of the spinal cord). The cavity is filled with cerebrospinal fluid.

Cycling, boxing, baseball, horseback riding, soccer, basketball, wrestling, rugby, water sports, and winter sports are among the 20 most causative agents of brain injury treated in U.S. hospital emergency rooms.

The common forms of injuries are as follows.

Concussion (Mild Traumatic Brain Injury, MTBI). These are head injuries with a transient loss of brain function, resulting in physical, emotional, or cognitive symptoms. They occur due to either impact or impulsive forces. These are diffuse brain injuries and occur in both contact and noncontact sports. They are graded based on severity as follows:

> *Grade 1:* No loss of consciousness occurs. Posttraumatic amnesia is absent or occurs for less than 30 minutes.
>
> *Grade 2:* Loss of consciousness occurs for less than 5 minutes. Posttraumatic amnesia remains for more than 30 minutes and up to 24 hours.
>
> *Grade 3:* Loss of consciousness occurs for more than 5 minutes and posttraumatic amnesia for more than 24 hours.

Players who suffer from Grade 1 or 2 concussions can return to play if they are asymptomatic for a week. Athletes with Grade 3 concussion have to be sidelined for a month.

Second-Impact Syndrome. When a second concussion is suffered during the course of recovery from the previous episode, it results in acute, usually fatal, brain swelling known as *second-impact syndrome*. Boxing, football, ice or roller hockey, soccer, baseball, basketball, and snow skiing have a higher incidence of this condition.

Coma. Coma is defined as lack of consciousness. Athletes with severe head injuries may become comatose, which may result in permanent brain damage.

Intracranial Hematoma. Sports injuries may result in epidural or subdural (above or below the dura mater) hematomas. These are severe injuries; unconsciousness occurs, and the injury is sometimes fatal.

Treatment

Airway, breathing, and circulation (ABCs) must be maintained. CT scan and magnetic resonance imaging (MRI) scan provide the most important information about the type of injury and its treatment.

Prevention

Headgear must be worn in contact sports to prevent such injuries.

Lung

The lungs are situated bilaterally in the thoracic cavity, covered by a serous membrane known as *pleura*. It is divided into different lobes and is protected by the rib cage.

Types of Injuries

Pulmonary Contusion. It occurs in injuries from blunt trauma involving high velocity. It results in severe lack of oxygen in blood.

Pulmonary Barotraumas. Heavy exertion and rapid ascent during diving are the common causes. Overpressure of 95 to 110 centimeters (cm) of water can result in lung damage.

Pneumothorax. This is caused by the presence of air or blood (hemothorax) in the pleural space due to penetrating injuries of the chest or rib fractures and compromised breathing.

Diagnosis

The extent of contusions is diagnosed by CT scans. Absence of breathing sounds and wheezing on chest auscultation and chest X-rays can help detect pneumothorax.

Treatment

Resolution of the contusion occurs in a few days, so oxygen support is needed only for severe cases. Pneumothorax of 15% to 20% or less can be treated with rest and oxygen therapy. A 20% or greater injury requires hospitalization.

Testicular Injury

This type of injury occurs as a result of a direct blow to the scrotum, causing compression of the testicles against the pubic bones.

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See also Cardiac Injuries (Commotio Cordis, Myocardial Contusion); Contusions (Bruises); Football, Injuries in

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Orthopedist in Sports Medicine, Role of

The field of orthopedics is concerned with the diagnosis and treatment of derangements of the bones, joints, ligaments, and muscles. The first reference to the term was in 1741, in *Orthopaedia: Or the Art of Correcting and Preventing Deformities in Children.* The author, Nicholas Andry, derived the term from the Greek words *ortho* (straight) and *paedia* (rearing a child). The origins of orthopedics are intimately related to the treatment of skeletal deformity in children.

The first orthopedic hospital was established in 1780 by Jean-Andre Venel for the treatment of children. Since its early beginnings, orthopedics has expanded to many subspecialties. Areas of specialty training include pediatrics, spine, trauma, joint replacement, tumor, and sports. Today, only a few orthopedic surgeons focus on correcting deformity in children. The general orthopedic surgeon sees a disproportionate number of adults in the treatment of fractures, sports injuries, and joint replacement.

History of the Orthopedist and Sports Medicine

Conceptually, the field of sports medicine is thousands of years old. The ancient cultures used exercise in some form to promote health and healing. In ancient China, the use of exercise and breathing to improve congested organs was known as kung fu. Herodikos of Selymbria, in ancient Greece, is often considered the father of sports medicine. Prior to studying medicine, he was a sports teacher. At the medical school of Cnidus, he described the imbalance between diet and exercise, resulting in bad health. Later in his text "On Diet," Hippocrates noted that "in order to remain healthy, the entire day should be devoted exclusively to ways and means of increasing one's strength and staying healthy, and the best way to do so is through physical exercise."

Modern sports medicine focuses on the benefits of exercise and promotes the health of athletes. There are a number of organizations that have been integral in the growing field of sports medicine. The International Federation of Sports Medicine (FIMS) was established in 1928 to assist the athletes of the Winter Games in St. Moritz. In 1950, the National Athletic Trainers Association was founded for the education of athletic trainers. In 1951, the American Medical Association established a committee on Injuries in Sports, which is now a standing committee. The American College of Sports Medicine was created in 1954 and is now the largest sports medicine organization in the world. More recently, the American Orthopedic Society for Sports Medicine was founded in 1971.

In the infancy of sports medicine, the orthopedist was synonymous with the treatment of musculoskeletal complaints. When an athlete was injured, he or she saw an orthopedist. There were fewer operative options, and the majority of injuries were treated with some type of rest and bracing. As the field of sports medicine expanded, the role of the orthopedist evolved. There are now numerous examples of orthopedic surgeons facilitating athletes' return to sports, even at the highest level. In the 1970s, Frank Jobe enabled Tommy John to return as a professional pitcher for the Dodgers by reconstructing the inner ligament of his elbow. In 2009, Tiger Woods was able to return to professional golf after the reconstruction of the anterior cruciate ligament of his knee.

Currently, the field of sports medicine encompasses a wide range of practitioners. The orthopedist is now often considered the technician of the sports medicine world. He or she is a surgeon by trade. The physician has to complete a minimum of 10 years of postsecondary education. The training to become an orthopedist focuses on the diagnosis of musculoskeletal problems and their treatment. In the office, injections of the joints can be given to help diagnose or treat a problem. The ultimate decision for surgery lies in the hands of the orthopedist. He or she incorporates diagnostic information from imaging with clinical information from the history and physical exam to make this decision. Whereas the orthopedist reviews the findings of the radiologist, it is often necessary to have the radiographs and magnetic resonance imaging (MRI) scan present in the office for decisions regarding surgery.

Sports Medicine Fellowship in Orthopedics

Some orthopedists undergo additional training in sports medicine. This year of training focuses on athletic injuries and their treatment. Many of these injuries can be treated with minimally invasive techniques. A common tool of the sports medicine orthopedist is the arthroscope. The use of diagnostic arthroscopy was first described in the 1920s by Eugen Bircher. The technique has been expanded to perform many procedures of the joints. From 1999 to 2003, the most common orthopedic procedure performed was knee arthroscopy with partial meniscectomy, followed by shoulder arthroscopy with decompression. A small incision is made at the knee, shoulder, ankle, elbow, or hip for the insertion of an underwater camera. Clear sterile fluid, normal saline, flows into the joint as the sports surgeon is able to directly visualize the bones, ligaments, and tendons. Another small incision is made at the skin for the insertion of instruments to help treat the problem. This is often referred to as a "scope." Arthroscopy has allowed patients to return to sports within days after procedures that formerly had required a recovery period of weeks to months.

Orthopedic Scientist

As with most fields of medicine, there is constant progress. There is a steady influx of nutritional supplements that claim to give the athlete an advantage. New techniques are developed to return players to the field more efficiently and effectively. The media often sensationalize new products. The orthopedist has a role interpreting the literature and educating the community. This can be accomplished by talks to the community or by spending time with the patient in the office to reach an informed decision regarding treatment.

Patient's Advocate

The orthopedic physician is first and foremost an advocate for the athlete. This can at times conflict with the patient's relationship with other members of the team, including the coach. The orthopedist has a responsibility to protect the player by limiting exposure to environments and conditions that could injure the athlete and only allowing the player to return when fully recovered from injury. This role of patient's advocate is exemplified by recommendations for the adolescent athlete. In baseball pitchers, restricting the number of pitches that can be thrown in a period of time reduces overuse injuries to the shoulder and elbow. The orthopedic surgeon has an obligation to inform the athlete of the conditions and treatments that could pose future risks. In elite female athletes, the rigors of training can lead to a dangerous condition resulting in amenorrhea, the absence or suppression of menstrual flow, and osteopenia, or low bone density. Disordered eating is also often a component of the condition known as the *female athlete triad.*

Relationship With Other Specialists

Typically, there is a close interaction between the orthopedist and the physical therapist. Many conditions that require treatment can be overcome with proper physical therapy modalities. The decision for surgery is a major one but is only part of the solution. For the athlete to progress through the rehabilitation process, it is necessary for communication between the surgeon and the physical therapist. Not every procedure is the same, of course, and the orthopedist should participate in the design of a rehabilitation program tailored to what was found and accomplished in the operating room.

In large practices, there are often multiple specialists to diagnose and treat sports-related problems. The sports medicine orthopedist works closely with many other sports medicine specialists and clinicians, including family physicians, emergency physicians, pediatricians, athletic trainers, and physical therapists, to improve the identification, prevention, treatment, and rehabilitation of sports injuries. In some situations, the athlete is first seen by a primary care sports medicine specialist and then referred to the orthopedic surgeon when there is an indication for surgery or a question as to the diagnosis. In smaller practice settings, the orthopedist is often the first to see the athlete with a musculoskeletal complaint. The majority of these injuries can be treated without surgery, necessitating an understanding of the nonoperative management of these conditions with physical therapy and bracing.

Athletic Events

In the setting of athletic events, there is often an orthopedist present. As a physician, he or she is trained in emergency medical management of injuries. These include head injuries, spine injuries, and cardiac emergencies. On the athletic field, the orthopedist is the coordinator of care for the injured patient. While there is a myth that has been perpetuated by the media industry that the orthopedist will simply give the player a "shot" and send him or her back into the game, this is rarely the case. Typically, there is an on-field assessment of the player. Emergent conditions are ruled out, and the player is assisted to the sideline. On the sideline, further evaluation of the player is conducted. The patient's orientation is assessed to rule out concussion (see the entry Concussion). If there is any question of an injury that could lead to further impairment with return to play, the athlete is held on the sideline until further workup can be performed. Once again, there are many components of the sports medicine team. The orthopedist typically relies on the trainers and the physical therapist for treatment of minor injuries with taping, massaging, and stretching.

Conclusion

In conclusion, orthopedic surgeons are intimately involved in all levels of sports. These include protecting the young athlete from overuse injuries, assessing injured players on the field, diagnosing injuries sustained in athletic events, providing operative management for those injuries that do not respond to physical therapy, educating the community, and playing a leadership role in expanding the field of sports medicine through research.

Matthew Diltz

See also Back Injuries, Surgery for; Concussion; Elbow and Forearm Injuries, Surgery for; Foot and Ankle Injuries, Surgery for; Hand and Finger Injuries, Surgery for; Hip, Pelvis, and Groin Injuries, Surgery for; Knee Injuries, Surgery for; Lower Leg Injuries, Surgery for; Running a Sports Medicine Practice; Shoulder Injuries, Surgery for; Sports Injuries, Surgery for

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Orthotics

Orthotics is the medical field concerned with the design, development, and fitting of orthoses, which are devices that support or correct imbalances in the musculoskeletal system. Those who fit and apply orthoses are known as orthotists.

In sports, the term *orthotics* refers to any type of formed or prefabricated device that corrects musculoskeletal abnormalities that limit or affect participation in sports.

Orthoses have a wide array of medical uses. These range from simple orthoses that support a single injured limb to complex structures used in the rehabilitation of patients with serious medical problems such as stroke and spina bifida.

The development of orthotics began in ancient times with splint and brace making. Especially over the past 40 to 50 years, the field has developed and grown, particularly with the development of thermoplastics—plastics that can be warmed and molded to an area of the body and retain their shape after cooling.

Different Types of Orthoses

There are two major types of orthoses: custom and prefabricated.

In general, prefabricated orthoses are formed based on a "normal" anatomic model and are usually obtained over the counter. This type of orthosis is typically mass manufactured and is therefore cheaper than custom orthotics.

Custom orthoses are typically fit to a specific patient by an allied health professional, such as an orthotist. These are typically formed using a mold and then are made specifically for the patient. In general, these are more expensive and are often favored by athletes.

Orthoses for the feet are the most common class of orthotics. Because of the weight bearing associated with most forms of work and sports, foot orthotics are extremely popular. These range from over-the-counter "shoe inserts" to custom orthotics molded to the foot. Some orthotics are made simply to provide comfort, while others are formed to help with correction of structural abnormalities.

Orthotics are generally either "soft" or "rigid." Rigid orthotics are formed to maintain the body part (typically the foot) in proper position. An example of this type of orthotic is an ankle-foot orthotic (AFO), which is prescribed for patients who suffer from foot drop as a result of a stroke or other injury to the peroneal nerve. Soft orthotics are used for cushioning and can be used in a variety of medical conditions, such as plantar fasciitis or diabetes; these are also sometimes called "accommodative" orthotics.

Developments in Orthotics

Over the past two decades, there has been a movement in sports toward helping keep the foot in what is thought to be the most anatomically correct position. Particular attention is paid to maintenance of the arch of the foot, as well as maintaining the foot in a subtalar neutral position (the normal position of the foot when walking) as much as possible. This development has resulted in the formation of semirigid and calibrated orthotic devices. Semirigid orthotics are made of a mixture of soft and rigid materials and are used to correct abnormalities such as flat feet (pes planus) and inward rolling of the foot (overpronation), and these are very popular among athletes. Calibrated orthotics also take into account other factors such as body weight and flexibility to provide greater levels of support.

Daniel S. Lewis

See also Flat Feet (Pes Planus); Foot Injuries; High Arches (Pes Cavus); Podiatric Sports Medicine

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Os Odontoideum

The structures of the neck include the cervical portion of the spine, consisting of seven cervical vertebrae. The top two vertebrae, C1 (atlas) and C2 (axis), have an anatomy different from that of the lower cervical vertebrae to provide for much of neck rotation and nodding. In the lower cervical vertebrae, C3 through C7, each vertebra has an anterior cylindrical structure called the vertebral body, with a posterior bony canal housing the spinal cord. Each vertebral body is separated above and below by a cervical disk. At the axis, however, there is a superior projection of the vertebral body called the odontoid process (also called the dens), which goes up into the anterior ring of the atlas (Figure 1a). The dens takes the

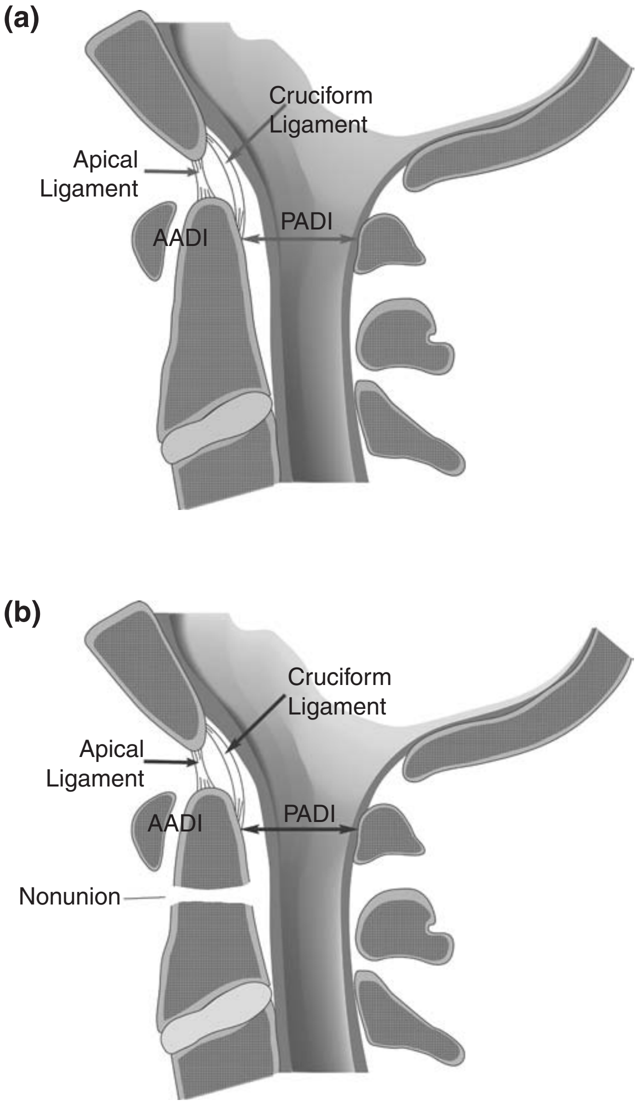

Figure 1 (a) Normal Upper Cervical Spine, Lateral View, and (b) Os Odontoideum, Showing Separation (Nonunion) of the Dens From the C2 Vertebral Body

Source: Illustration by Michael d'Hemecourt.

Note: AADI = anterior atlanto-dens interval; PADI = posterior atlanto-dens interval.

place of the disk and acts as a pivot point for rotation of the atlas on the axis. In early life, this dens is separated from the main body of C2 by a cartilaginous layer called the synchondrosis. During young age, this layer fills in with bone, becoming almost indistinct.

An important ligament, the *transverse atlantal ligament,* holds the dens to the anterior aspect of the axis, away from the posterior placed spinal cord. Maintaining this relationship away from the posterior spinal canal is very important for the integrity of the spinal cord. When this relationship of the dens in the anterior aspect of the atlas is compromised, it is referred to as *instability*. Certain traumatic events can compromise this integrity, such as fracturing the dens or disrupting the ligament. Certain chronic conditions can also cause some compromise. One of these chronic conditions is an *os odontoideum*. This refers to a separation of the top of the dens from the C2 vertebral body (Figure 1b). Other odontoid abnormalities include rare complete or incomplete dens formation. Another chronic condition in this category of instability of C1 and C2 is ligamentous laxity of the transverse atlantoaxial ligament, seen in Down syndrome. Any of these entities has severe implications for sports that involve contact and collision.

The etiology of os odontoideum is controversial with respect to its being traumatic versus congenital in origin. Supporting a theory of a trauma in the distant past are multiple case reports of patients with an os odontoideum and a history of previous unrecognized traumatic events in early childhood. Since older fractures often have a well-rounded appearance, the rounded os odontoideum lends credence to its having been a previous fracture through the synchondrosis before it filled in with bone. Conversely, other case reports indicate a congenital abnormality as there are often other associated spinal formation deformities, such as incomplete arch closure, as well as other nonspinal congenital malformations. Nonetheless, the etiology is not as important as detecting this and determining its stability.

When the dens loses stability with the axis, there is the potential for spinal cord injury, especially in the motion of flexion. In this case of instability, flexion will widen the gap of the dens and the axis. This increased atlanto-dens interval (ADI) may substantially compromise the posterior spinal canal. The normal ADI is less than 3 millimeters (mm) in the adult and 4 to 5 mm in the young child. Intervals above this are abnormal and referred to as unstable. Another problem with instability at this level is compromise to the small vertebral arteries (the vertebrobasilar arteries) that travel along the outer parts of the vertebrae to supply blood to the posterior parts of the brain. As such, these patients may present intracranial symptoms due to vertebrobasilar artery insufficiency, such as dizziness and double vision.

Natural History

This entity is a critical issue for athletes who participate in collision sports. The strong concern is that even minor contact may cause permanent catastrophic spinal cord injury. Understanding the natural history of the entity may help the athlete understand why he or she should withdraw from collision sports.

Usually, these structural abnormalities are incidentally detected on radiographs for other reasons. However, some are symptomatic. The symptoms can be placed in three categories: pain syndromes, myelopathy, and intracranial symptoms. Pain is the most common accompanying symptom, but myelopathy is more catastrophic. *Myelopathy* refers to spinal cord injury patterns that can present with weakness and spasticity of the extremities as well as clumsiness and the inability to hold urine or stool. Myelopathy may be transient with a minor traumatic event or progressive.

Once one detects an os odontoideum, one must classify the type of symptoms experienced by the patient as well as the amount of instability and posterior spinal cord impingement. There are no long-term studies that look at the true incidence of an os odontoideum. However, numerous studies have looked at the outcomes of patients with varying degrees of instability and myelopathy treated both conservatively and surgically. Patients with instability or myelopathy do well with surgical fusion of C1-C2. However, some small case reviews show patients with mild myelopathy and instability doing well with conservative management over a short follow-up time of 3 years. Patients without instability or myelopathy seem to do well if treated conservatively. Nonetheless, there have been some reported cases demonstrating progression to instability and myelopathic changes with minor traumatic episodes. This latter experience is one reason why collision sports are contraindicated.

Imaging

Plain radiographs are usually sufficient to detect the presence of an os odontoideum. This would include an anteroposterior (AP), lateral, and open-mouth odontoid view. As mentioned previously, instability at this level is a problem for the spinal cord. This is typically measured on the lateral radiograph by the ADI. However, a more sensitive measurement of spinal canal compromise is the posterior atlanto-axial interval (PAAI). This latter issue appears to be the most significant with respect to development of myelopathy. Dynamic radiographic evaluation should include lateral flexion and extension views, with attention to instability. A posterior atlanto-dens interval (PADI) less than 13 mm indicates instability with cord impingement and neurologic decline. An ADI interval of greater than 5 mm is also a sign of instability. Any of these findings may indicate the need for surgical stabilization.

Computed tomography (CT) scanning may be helpful in presurgical evaluation of associated anomalies at the cervico-occipital juncture. Magnetic resonance imaging (MRI) is very useful to determine cord compression as well as myelopathic changes in the cord not apparent on the CT scan.

Treatment

Patients who have an os odontoideum found incidentally should be evaluated for instability with dynamic radiographs. If this is found, an MRI scan is useful in determining myelopathy. For those patients without symptoms of instability, nonoperative management is a reasonable approach. However, because delayed instability has been reported, follow-up of the patients should be done to reconfirm stability. Most authors have recommended surgical stabilization for those patients with instability and/or myelopathic changes. Surgical stabilization usually involves using a bone graft to fuse the C1 and C2 vertebral bodies. This is often reinforced with posterior wires or screw fixation. Overall, patients treated with these fusions do well, with nonunion being a small but possible complication. Some reports have shown that some patients treated conservatively even with mild instability have done well at follow-up. However, most investigators still recommend stabilization in these patients because of the possibility of catastrophic instability with mild trauma.

Return-to-Sports Considerations

Unfortunately, there is no allowance for these athletes to return to collision sports. Even in the athlete with no instability documented on flexion and extension views, catastrophic injury is still a possibility. There are documented cases of delayed instability in those who were initially stable. Furthermore, acute traumatic instability at this level could cause disastrous neurologic injury and be life threatening. Even if the athlete has a solid C1-C2 fusion with resultant stability as seen on dynamic radiographs, collision sports are contraindicated. Although a single-level fusion is not an absolute contraindication below this level, a C1-C2 fusion is considered unstable. These athletes may participate in noncollision and noncontact sports. Those without surgical stabilization should be monitored indefinitely with dynamic radiographs for development of instability.

Pierre A. d'Hemecourt

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Osgood-Schlatter Disease

Osgood-Schlatter disease, or syndrome, is a rupture of the growth plate at the tibial tuberosity, a form of apophysitis first described by the physicians Robert Bayley Osgood and Carl Schlatter separately in 1903. It is one of the more common sources of anterior knee pain in the preteen athlete and the teenage athlete. This condition most commonly occurs from ages 8 through 13 in females and ages 10 through 15 in males, although certainly those with earlier or delayed growth may present at other ages. Males seem to be affected at a slightly higher rate than females. Both knees can be painful in up to 30% of athletes.

Anatomy

Osgood-Schlatter syndrome is a disorder of the *apophysis*. An apophysis is an area of bone growth, although growth at the apophysis does not result in a person becoming taller. The apophysis serves as an attachment site for a tendon. In Osgood-Schlatter syndrome, the tibial tubercle apophysis is the affected area, which is located on the upper end of the tibia, which is the larger of the two shinbones. The patellar tendon originates from the lower portion of the patella (or kneecap) and attaches to the tibial tuberosity.

Pathogenesis

Osgood-Schlatter syndrome is considered a traction apophysitis, meaning that the traction of the patellar tendon on the growth area at the tibial tubercle produces the signs and symptoms of this condition. With physical activity, particularly running and jumping, the stresses of the patellar tendon on the apophysis put traction on the apophysis. This can lead to mild separation or fragmenting of the apophysis. As the athlete continues to grow, the fragmented area may continue to add an additional bone, and a prominent bony bump may occur at the tibial tubercle, giving the typical appearance of the lump below the patella that many patients present with. Decreased flexibility in the quadriceps or hamstring muscles may develop as the athlete goes through a rapid growth spurt, which will put additional traction on the affected area and contribute to the problem (Figure 1).

Presenting Signs and Symptoms

Affected athletes will present with pain with activity, most frequently due to running or jumping. Many will describe pain with kneeling or any direct pressure put on the knee. Pain is localized over the tibial tuberosity. Swelling or a prominence of the tibial tuberosity is often reported and noted on exam. Occasionally, a limp will occur.

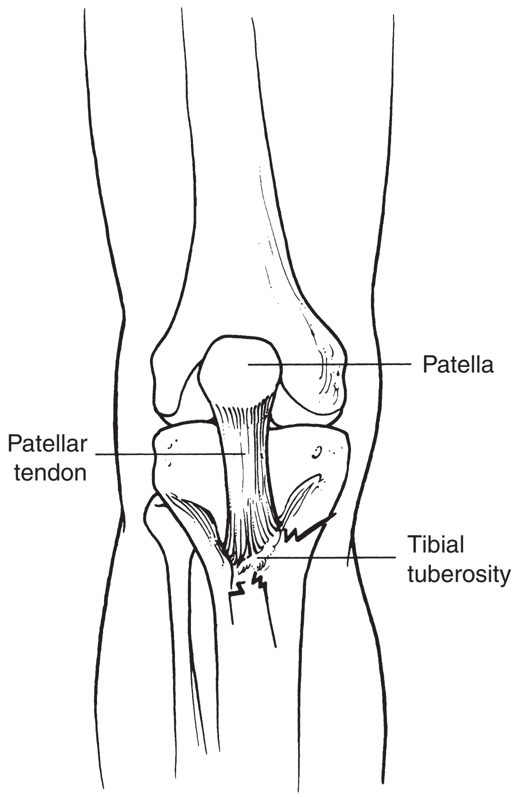

Figure 1 Tibial Tuberosity

Notes: In children, repetitive knee-bending activities may cause irritation at the tibial tuberosity, where the patellar tendon attaches. Athletes 9 to 14 years old are at most risk.

A less common injury, although it should not be considered a complication of Osgood-Schlatter syndrome, is an avulsion fracture of the tibial tuberosity, in which the athlete loses the ability to extend his or her knee. A deformity is noted below the patella when this occurs. The athlete will not be able to walk on the affected leg and will lose the ability to extend his or her knee, similar to a patellar or quadriceps tendon rupture in an adult.

Physical Exam Findings

On physical examination, the athlete may have a prominent bump over the upper end of the tibia. There may be overlying soft tissue swelling over the tibial tuberosity. Often, there will be pain when the athlete is asked to straighten his or her knee from a bent position against the resistance of someone holding on to the front of his or her shin. By definition, there must be tenderness with pushing directly over the tibial tuberosity. Swelling in the knee joint is not present. In more severely affected patients, there may be a noticeable limp while walking.

Radiologic Findings

X-ray studies are not necessary to make the diagnosis of Osgood-Schlatter syndrome. Patients with pain in one knee only, progressively worsening pain, limping, or nighttime pain may benefit from radiographs to evaluate for other problems such as tumors, infections, or stress fractures. Common findings on X-ray include widening of the apophysis compared with the nonpainful side or development of ossicles, which are small fragmented bones or calcifications in the patellar tendon.

Treatment

The mainstay of treatment of Osgood-Schlatter syndrome is nonsurgical. In those with milder symptoms, treatment may include decreasing activity, such as the duration or frequency of the painful activities. The use of ice after activity may be helpful and is encouraged. Bracing with a patellar tendon strap, which wraps around the patellar tendon, situated just below the lower end of the kneecap but above the painful area, may help. This reduces some of the traction on the tibial tuberosity. For athletes who have to kneel and put direct pressure on the painful area, a knee pad may be helpful. Anti-inflammatory medications, such as ibuprofen or naproxen, may be helpful after activity for pain relief but should not be encouraged prior to activity to avoid masking the increasing pain that may help cue the athletes that they should stop their activity.

Physical therapy may be helpful in focusing primarily on stretching of the quadriceps, hamstrings, and calf muscles. Strengthening of the quadriceps muscles, especially while the athlete is still experiencing pain, may aggravate this. Rarely, an athlete may benefit from immobilization if he or she is in significant pain with daily activities.

Surgery is considered for patients who have finished their growth and have persistent pain despite attempts at nonsurgical treatment.

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See also Back Injuries, Surgery for; Cervical and Thoracic Spine Injuries; Lower Back Injuries and Low Back Pain; Musculoskeletal Tests, Spine; Neck and Upper Back Injuries

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OSTEITIS PUBIS

Osteitis pubis is characterized by inflammation of the pubic symphysis and the adjacent bones. This inflammation leads to bony changes of the pubis symphysis, causing both acute and chronic groin pain. The condition is one of the most common causes of chronic groin pain in athletes, but it may affect nonathletes as well. Osteitis pubis is a self-limited condition that resolves with time, but a variety of treatment modalities may be used to treat the symptoms.

Anatomy

The pelvis is a bony structure that connects the lower spine and trunk to each of the lower extremities. The pelvis is composed of two bony structures known as the os coxae (hipbone). There is a left and a right os coxa. Each os coxa consists of three bones (the ilium, ischium, and pubis) that are fused together. The muscles of the abdomen, groin, and thigh attach to the bones of the pelvis. The two hipbones are joined anteriorly (in the front) at the pubic symphysis and posteriorly (in the back) to the base of the spinal column. The pubic symphysis is the midline cartilaginous joint uniting the left and right pubic bones. It includes a cartilaginous disk that is approximately 3 to 5 millimeters (mm) wide.

Causes

Osteitis pubis is an inflammatory lesion of the pubic symphysis. It is commonly seen in athletes, but it may also be seen during or after pregnancy and after prostate or bladder surgery. Although its exact cause is undetermined, in athletes it is associated with mechanical strain from trauma and repetitive twisting and cutting movement. These actions cause the abdominal and groin muscles to exercise a pulling or traction force on the pubic bone, which in some cases can result in excessive stress and inflammation. Osteitis pubis most commonly affects long-distance runners, weight lifters, ice hockey players, swimmers, fencers, soccer players, football players, and Australian-rules football players.

Symptoms

Increased stresses across the pubic symphysis lead to inflammation and groin pain. Patients report a gradual onset of groin pain, which may be felt on one or both hips. The pain may radiate into the inner aspect of the thigh, groin area, scrotum, or testicles or into the abdomen. This pain worsens with kicking, running, jumping, abdominal straining (e.g., coughing or doing sit-ups), or pivoting on one leg. In addition to pain, osteitis pubis may also be associated with instability of the pubic symphysis and/or loss of hip range of motion.

Diagnosis

The diagnosis of osteitis pubis is made by correlating the patient's history of symptoms with characteristic physical examination and radiographic findings.

Physical Examination

Tenderness along the upper border of the pubic bone and pubic symphysis directly beneath the skin are the characteristic findings on physical examination; lack of tenderness in this area rules out the diagnosis of osteitis pubis. Pain is often present when the examiner outwardly moves the patient's leg away from the body (hip abduction). In addition, having the patient attempt to bring the leg back toward the body (hip adduction) while

X-ray of a normal pelvis, including the two pubic bones (white arrows) and the pubic symphysis (gray arrow)

Source: Adam J. Farber, M.D.

X-ray showing the pelvis in a patient with osteitis pubis. Note the widened pubic symphysis and irregular edges of the left and right pubic bones (circle).

Source: Adam J. Farber, M.D.

the examiner resists this motion will also typically elicit pain. Limitations in hip rotation also may be seen on physical examination.

Radiographic Findings

Plain radiographs (X-rays) are a critical part of the work-up of suspected osteitis pubis. On X-ray, the pubic symphysis normally appears as a dark space between the two ends of the pubic bones, which normally have smooth, regular edges. Occasionally, in cases of osteitis pubis, the X-rays will be normal and show no abnormalities because findings may not be apparent for 2 to 4 weeks after the onset of symptoms. The typical radiographic findings of osteitis pubis include bone resorption of the ends of both the left and the right pubic bones; this leads to irregular margins at the ends of the pubic bones. The other classic radiographic finding seen with osteitis pubis is widening of the pubic symphysis; this appears as a widened (>5 mm) dark space between the two ends of the pubic bones. Gradual reossification (reformation of bone) with complete restoration of the pubic symphysis joint is seen with healing, but this may take several months.

X-rays taken with the patient standing on one leg (known as "flamingo" views) are beneficial if instability of the pubic symphysis joint is suspected. Instability is defined as >2 mm of height difference between the ends of the pubic bones at the pubic symphysis.

Bone scans are also diagnostic but are not typically needed to make the diagnosis. Early in the course of the disease, bone scans show diffuse increased uptake unilaterally or bilaterally in the pubic bones.

Magnetic resonance imaging (MRI) findings are also diagnostic for osteitis pubis, but an MRI scan is not typically required to make the diagnosis. MRI findings include increased fluid in the pubic bones (often in both the left and the right pubic bones) early in the course of the condition, followed by decreased fluid and thickening of the bones as the disease progresses.

Treatment

Osteitis pubis is a self-limiting condition that requires no treatment other than time. However, despite its self-limited nature, osteitis pubis tends to have a protracted course, and 6 to 9 months or more may elapse before the athlete can return to the pre-injury level of functioning. During this time, a variety of nonoperative treatment modalities may be used to treat the symptoms, but this will not affect the ultimate course of the condition. Treatment options include activity modification (especially avoiding vigorous sports activities that involve running, jumping, kicking, and twisting motions), ice, nonsteroidal anti-inflammatory drugs (NSAIDs), stretching, strengthening, hip range-of-motion exercises, and physical therapy modalities. If symptoms persist despite these treatment measures, corticosteroid injections may be considered in an attempt to hasten the recovery process. The steroid injection is most effective if given within 2 weeks of the onset of symptoms.

Rarely, in chronic cases that are unresponsive to nonoperative therapy and injections, surgical treatment options may be considered. One procedure entails fusing the two pubic bones together (also known as arthrodesis) at the pubic symphysis if symphyseal instability is present. Another surgical option involves surgically removing the ends of the pubic bones adjacent to the pubic symphysis. These options are rarely pursued and are associated with unpredictable results.

Adam J. Farber

See also Anatomy and Sports Medicine; Groin Pain; Hip, Pelvis, and Groin Injuries; Hip, Pelvis, and Groin Injuries, Surgery for; Sports Injuries, Overuse

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Osteoporosis Prevention Through Exercise

Osteoporosis is a disease that affects the density of bones. Bones gradually become weak due to loss of calcium, making them more susceptible to breaking. More than half of Americans have some loss of bone density, also called *osteopenia,* or low bone mass, and are at risk for osteoporosis. The majority of people with osteoporosis are women, but osteoporosis also affects men. Osteoporosis can occur at any age but is more common in people 50 years of age or older. Certain strategies exist that can help decrease the risk of developing osteoporosis.

Bone Health

Bone mass develops early in life. The majority of a person's bone mass is established by 20 years of age, and bone density peaks by the late 20s or early 30s. After this peak occurs, bones slowly lose mass through the rest of the life span. The speed of bone loss depends on a number of factors. Women tend to lose bone mass more quickly than men, and the rate of loss for women increases after menopause.

Maximizing Bone Density

A number of methods exist for maximizing bone density during the early decades of life and minimizing bone loss throughout life.

Nutrition

Adequate intake of calcium and vitamin D is essential to optimize bone density during bone formation. The amount of calcium and vitamin D needed varies depending on one's age, sex, and activity level. Preteens and teenagers should consume at least 1,300 milligrams (mg) of calcium per day along with at least 400 international units (IU) of vitamin D. It is better to obtain calcium and vitamin D from natural sources, but supplementation is recommended if the intake is not enough. Continuing to obtain appropriate amounts of these minerals throughout life will also help decrease the rate of bone loss.

Lifestyle Choices

Smoking increases the risk of developing osteoporosis. Patients who avoid smoking or quit smoking decrease this risk. Excessive alcohol intake also increases the risk. Consuming alcohol in moderation can be helpful to limit the negative effect of alcohol on bone density.

Exercise

Exercise helps build bone density. Specifically, exercise that is considered high impact is the best. These types of exercise involve weight bearing, being on one's feet, and movement so that the feet repetitively strike the ground. Examples of high-impact exercise are aerobics, running, and basketball. Resistance exercises, such as lifting weights or using exercise bands, can also help keep the bones strong.

If a patient cannot participate in high-impact exercise, any exercise will still be better than none. Using an elliptical machine or walking can be beneficial for bone health as well. Exercises that can increase balance can help prevent falls and decrease the risk of breaking bones, even in patients with osteoporosis.

While it is best for bone health to take in plenty of calcium, avoid smoking, and exercise early in life to build the maximum bone density possible, it is never too late to start an exercise program. Elderly patients with osteoporosis still benefit from starting an impact exercise program. Nursing homes have started to include interactive video games for senior citizens to increase participation in activities. It is too early to determine to what extent these programs will help with increasing bone density and decreasing fracture risk, but increasing the activity level of this group of people is a positive step.

Diagnosis of Osteoporosis

Physicians look for clues of decreasing bone mass during physical examinations. Loss of height or increasing curvature of the spine as patients age can be signs of weakening bones. If a decrease in bone density is suspected, a bone density test, or a dual-energy X-ray absorptiometry (DEXA) scan, should be obtained. This test will compare the density of the patient's bones with that of a young adult of the same sex with peak bone mass, giving a degree of how thin the bones have become. Some guidelines exist that recommend routine screening for osteoporosis at a certain age depending on what other risk factors are present.

Treatment of Osteoporosis

Good nutritional intake, adequate amounts of calcium and vitamin D, and exercise all play a role in helping maintain bone density. Medications also exist that can decrease the rate of bone loss and help limit the risk of fractures. Unfortunately, these medications also have potential side effects, and the benefits of the medications must be weighed against the risks. Discussion with a physician can determine which treatments are appropriate for an individual.

David Berkson

See also Benefits of Exercise and Sports; Dual-Energy X-Ray Absorptiometry (DEXA); Exercise Programs

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Outdoor Athlete

The *outdoor athlete* is a term applied to any athlete, recreational or professional, who enjoys exercising outside. The term encompasses a range of athletes from those who simply run outdoors to those who brave the elements in extreme outdoor sports. Though a wide range of talents exist among outdoor athletes, they all share one key thing in common: the love of the outdoors.

The outdoor athlete has some special considerations to think about before his or her workout. Since these athletes are not working out in a gym or other controlled environment, they must pay careful attention to their surroundings to ensure a safe, effective workout session.

Climate

Outdoor sports, from kayaking and whitewater rafting to ice climbing and cross-country skiing, cover a wide range of climates. An important consideration for all outdoor athletes is the climate in which they will be active. For those working out in hot, sunny conditions, careful attention must be paid to proper hydration, finding shade when needed, and sun protection. Recent studies have demonstrated that outdoor athletes are at an increased risk of developing skin cancer from excessive exposure to sunlight and thus must be careful and thoughtful about wearing sunscreen during their outdoor activities. At the other end of the spectrum, those choosing sports that are played in cold conditions must also ensure that they have proper hydration in addition to warmth.

The outdoor climate can also exacerbate underlying chronic medical conditions, such as allergies and asthma, in athletes, which may not be an issue during indoor exercise. Outdoor athletes who suffer such symptoms should discuss them with their doctor before continuing outdoor activities.

Severe allergies to plants and insect bites are other special considerations for outdoor athletes. Those who have a known possible anaphylactic reaction should always carry an epinephrine autoinjector with them while outdoors.

Gear

The market for outdoor sports gear has grown tremendously in the past few decades as outdoor and adventure sports become increasingly popular. Each particular outdoor sport has a unique niche for gear. The specifics of equipment for each individual outdoor sport are beyond the scope of this entry, but each outdoor athlete should be familiar with the proper safety and technical equipment for his or her sport.

As mentioned above, outdoor gear for all athletes includes protection from the sun as well as protection from insects and any other environmental factors. All water sport participants should wear life jackets.

Conditioning

Outdoor sports tend to involve uneven surfaces and often recruit the use of muscles that might not be used as much in indoor activities. For these reasons, specific strengthening and conditioning regimens will often help outdoor athletes prepare for and improve their performance in outdoor athletic activities. In addition, many outdoor sports, including climbing, skiing, snowboarding, and mountain biking, take place at higher altitudes. Each athlete will have to acclimate to these higher altitudes before reaching peak performance potential.

Specific conditioning regimens for each outdoor activity are also beyond the scope of this entry. Many outdoor magazines, websites, and personal trainers can offer tips for training and conditioning for specific outdoor activities.

Katherine S. Dahab

See also Cold Injuries and Hypothermia; Heat Illness; Lightning Injuries; Sunburn

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Ovary, Absence of One

The ovaries are part of the female reproductive system. There are normally two, one on each side of a woman's lower pelvis. The ovaries are responsible for producing the eggs that are released during a female's menstrual cycle as well as the production of the female sex hormones, estrogen and progesterone. Fertilization of the egg by a sperm will result in pregnancy.

Congenital absence of one ovary is rare and is usually associated with other abnormalities of the genitourinary tract. The genitourinary system includes organs involved in reproduction as well as urination. This system includes the kidneys, ureter, bladder, fallopian tube, uterus, and vagina. More commonly, women suffer the loss of an ovary due to a medical or surgical condition. An *oophorectomy* is the surgical removal of one or both of the ovaries. This may be necessary because of, but not limited to, the following conditions: symptomatic ovarian cysts unresponsive to conservative treatment, ovarian cancer, endometriosis (endometrial tissue occurring outside its normal location), ovarian abscess or infection, ovarian torsion (where the ovary gets twisted, loses blood supply, and dies), or known increased risk of ovarian caner due to a genetic mutation. Concern has been raised that participation in sports may pose a risk to those with one ovary, the concern being that if they lose the second ovary, it will render them infertile as well as menopausal.

In terms of sports participation, the absence of one ovary does not represent any contraindication. The ovaries are well protected within the lower pelvic region, and the risk of injury to the remaining ovary is minimal. The ovaries lie on the lateral wall of the pelvis on either side of a woman's uterus and are held in place by several different ligaments. This position places them deep within the pelvis, where they are relatively immobile and safe from outside forces or trauma. Therefore, athletes are able to participate in any type of sport and do not require any special protective measures or equipment even with the absence of one ovary.

Jessica Stumbo

See also Female Athlete

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Overpronating Foot

The biomechanics of gait are important in many conditions related to the foot, ankle, lower leg, knee, hip, and lower back. The most common abnormality involves the pronating foot. Overpronation is the overrotation of the foot toward the midline of the body that results in the relative flattening of the medial arch.

A small degree of pronation is normal—it helps absorb the shock while walking and running. Pronation is more commonly found than supination in the general population. An overpronating foot describes an abnormality where the foot spends a majority of the gait cycle in pronation and with weight bearing in general.

Gait Cycle

A review of the gait cycle is helpful in understanding this concept of overpronation and its contribution to injury. The gait cycle consists of four phases: (1) heel strike, (2) midstance, (3) toe-off, and (4) swing.

During the first two phases, the heel strikes the ground with the foot inverted or supinated (landing on the outside of the heel), and the ankle is dorsiflexed (the foot pointed up). This is followed by the foot pronating (rolling toward the inside) as the body weight is loaded onto the foot in midstance. During the last two phases, the foot supinates again as the weight shifts onto the toes, allowing the foot to propel and swing forward. During the cycle, the weight starts at the outer side of the heel and ends on the inside part of the front of the foot as one pushes off. Thus, pronation is a normal part of the gait cycle.

It is a simplification to refer to the pronating motion of the foot as "rolling inward," because it is a three-dimensional movement involving the foot turning away and the leg, knee, and hips rotating inward. Because of this kinetic chain, a small degree of overpronation can contribute to pain not just in the foot or ankle but also up the leg (medial tibial stress syndrome, or "shin splint"; posterior tibialis tendinitis, which causes pain along the inside of the ankle and leg), the knee (patellofemoral pain syndrome, or "kneecap maltracking"; pes anserine bursitis, which causes pain on the inside of the knee), and hip (iliotibial band syndrome, causing pain on the outside of the knee; trochanteric bursitis, causing pain on the outside of the hip).

Foot Anatomy

The arch of the foot is supported by three arches: (1) medial longitudinal, (2) lateral longitudinal, and (3) transverse midfoot arches. Of the three, pronation is the most closely associated with lowering of the medial longitudinal arch. You can either be born with a low medial longitudinal arch or acquire it with age or weight gain.

The posterior tibialis tendon provides additional support for the medial arch as it comes around the posteroinferior medial malleolus and makes its multiple attachments on the navicular, cuneiforms, and bases of the second, third, and fourth metatarsals. Because it helps control pronation, tendinitis is a common result of an overpronating foot.

Another important structure in the arch is the navicular bone, which interfaces with the talus bone, which sits at the base of the ankle, and the first, second, and third metatarsals or "foot bones." Situated at the "roof" of the arch, the navicular plays an important role, accepting and transmitting much of the foot's stress.

A common contributor to overpronation is pes planus, or "flat feet." Pes planus can be rigid or flexible, with the latter being more common. With a flexible pes planus, a flattening of the arch is noted only when standing or weight bearing. It is thus important to remember to always examine a patient's arch while the patient is standing. Pes planus, like overpronation, is not always pathological, as it is the normal foot shape in infants and in up to 20% of adults.

The persistence of pes planus in non–weight-bearing positions suggests a rigid pes planus. If this is found in a patient with pain, then an investigation into the causes, such as tarsal coalition or fusion of ankle bones, is done.

Physical Examination

The pronating foot in and of itself does not cause symptoms. Many people have pes planus and mild to moderate pronation but are completely without complaints or pain.

However, various structures, starting from the foot and moving up the kinetic chain, are subject to abnormal stresses with excessive pronation during the gait cycle. The symptoms vary depending on the condition associated with the pronating foot.

Common pronation diagnoses are listed below.

Foot and Ankle

- Plantar fasciitis
- Achilles tendinitis
- Posterior tibial tendinitis
- Tarsal tunnel syndrome
- Sinus tarsi syndrome
- Neuroma
- Metatarsalgia
- Hallux valgus
- Hammertoes

Lower Leg and Knee

- Medial tibial stress syndrome
- Patellofemoral syndrome
- Iliotibial band syndrome

As a result, physical examination of any patient presenting with pain in the lower back, hip, knee, leg, and foot or ankle should include an examination of the foot.

The foot examination consists of inspection, palpation, range of motion, and provocative tests. Inspection of the foot requires observing the foot from multiple views, including anterior (front), medial (inside), lateral (outside), and posterior (behind). The arch is best evaluated from the medial side and by comparing non–weight bearing with weight bearing to determine whether the flat foot is flexible or rigid. Looking from behind while the patient is standing also provides information about the biomechanics of the foot. In a patient with an acquired flat foot from posterior tibial tendon dysfunction, the calcaneus will be noted to have increased valgus. Another finding is the "too many toes sign," where more than two visible toes are seen lateral to the calcaneus when looking from behind the patient.

The patient should also be observed standing on his or her toes to see if the heels move into a normal varus position. Those with pes planus may have difficulty rising up on their toes on the affected side.

Because the conditions associated with the pronating foot are related to the repetitive stresses during walking or running, observing gait should also be included in the exam, analyzing the foot during the heel strike, midstance, toe-off, and swing phases.

Some specialty centers use video analysis or pressure pad recording to further evaluate and quantify excessive pronation and its consequences.

Treatment

As mentioned earlier, the presence of pes planus or a pronating foot does not require treatment if there are no problems (asymptomatic). If the pronating foot appears to be related to the patient's symptoms, correction of this can be useful, especially with chronic or recurrent conditions.

Mechanical support with a motion control shoe or over-the-counter orthotics are the first line of treatments for most mechanical foot problems involving overpronation. Most major shoe manufacturers offer motion control shoes to correct overpronation. The major feature of these shoes is a large and firm medial bar to prevent this excessive movement. Each shoe manufacturer may have a different name for this feature, but the key is that the patient understands its importance. Motion control shoes typically do not feel initially as comfortable as a cushioning shoe, so the novice athlete may gravitate toward a shoe that can actually aggravate his or her injury. This motion control feature, as with any component of the shoe, will break down with age and use, so the athlete needs to regularly replace shoes even if they appear in good condition superficially.

Over-the-counter orthotics may help up to 90% of patients. For those patients with unique anatomic needs, such as significant differences in pronation in one foot versus the other, custom orthotics should be considered.

Specific stretching and strengthening exercises can be helpful as well. A tight Achilles tendon is often associated with higher rates of symptomatic pes planus conditions. Therefore, a vigorous program of heel cord stretches is often helpful. Strengthening of the posterior tibialis muscle and tendon may be helpful since dysfunction or weakness of this muscle reduces support for the arch.

The rehabilitation program must also address other conditions associated with the pronating foot. A formal physical therapy program should be considered in those with persistent symptoms after attempting a trial of home exercises. Most conditions can be managed by a primary care physician, with orthopedic or podiatry referrals reserved for those who fail conservative management. Depending on the condition, surgery may be considered, as with hallux valgus that has failed conservative management.

Surgical management of an overpronating foot is almost never needed. The rare cases usually involve a rigid pes planus from a tarsal coalition that contributes to pain and limited motion.

John K. Su

See also Athletic Shoe Selection; Foot Injuries; Orthotics

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Oversupinating Foot

During walking and running, foot and ankle motion involves both pronation and supination. Understanding these foot biomechanics allows more precise prevention of injuries. This entry will describe the supination part of walking and running and how inappropriate supination can be assessed and managed.

Pronation Versus Supination

Pronation is a complex combination of movements that can be roughly described as a "rolling in" of the foot and ankle as the foot first touches the ground in a step. It is important for shock absorption and adapting to terrain changes. After the initial pronation, as a person's body continues to move forward over the foot during a stride, that foot and ankle need to "roll out," or supinate, for the foot to change from energy absorption of the foot strike to energy transfer of the push-off phase. During supination, the bones of the foot become more tightly compacted, so that when the leg muscles provide force, it is transferred efficiently to the ground for a fast, powerful stride. Without supination, the foot bones remain loose, and the ligaments trying to hold them together are susceptible to injury as the forces are transmitted not through the bones that are made for this task but through the ligaments, which may stretch and tear.

These actions can be seen by observing your own foot motions. While standing in stockings or on bare feet, roll your feet inward so that much of your weight is on the inner half of both feet. Then roll your feet out, so that most of the weight is on the outer half of your feet. Notice how much hip and knee movements are connected with these actions. If you find that you stand naturally with much of your weight on the inner half of your foot, you may be an overpronator. If you tend to stand with much of your weight on the outer half of your foot, and/or you find you are unable to roll inward, you are probably an oversupinator. It is the inability to pronate that is of most concern. Oversupinators are less common than either overpronators or persons with neutral foot mechanics.

Arch Height

There is a correlation between pronation/supination and the height of the arches. When a person with a low arch walks with wet bare feet at the swimming pool, he or she will leave a wide, almost oval footprint. A person with a high arch will usually leave a narrow footprint, because very little of the inner half of the footever touches the ground.

Many persons who overpronate have low or fallen arches. Virtually all persons who oversupinate have high rigid arches. However, the converse, that most persons with high arches are oversupinators, is not true. Some persons with high arches are able to pronate during the initial phase of a stride and would therefore not be considered oversupinators.

Foot Biomechanics

Ideal foot biomechanics would involve not only being able to stand with equal weight on the big and little toes but also having the ability to roll the foot inward so that the weight is more on the inner part. With ideal foot mechanics, the forces of running are transmitted efficiently to and from the pelvis. Many excellent athletes have less than perfect foot mechanics, and while they may be very successful, they are predisposed to certain injuries.

Lack of Shock Absorption

Oversupinators are unable to pronate and have more pressure on the outer half of the foot throughout the gait cycle. Thus, they are prone to skin and toe joint problems on the outer half of the foot. They also miss the shock absorption features of a more balanced foot mechanics, and this is where most problems arise. The lower leg forces of walking or running are not transmitted up to the hip and pelvis. Knee pain, especially lateral knee pain, may occur. The risk of stress fractures is higher. Oversupinators must pay attention to shin or foot pain that develops when running mileage is increased. Stress fractures that are not allowed to heal through activity modification can be very problematic.

Injury Prevention

To offset this lack of natural shock absorption, it is important to use other mechanisms for shock absorption. Oversupinators should run on soft surfaces as much as possible and work on a smooth technique. Attention to maintaining balanced strength and flexibility of hip and core muscle is critical. Cushioned orthotics, which will shift some of the pressure to the inner part of the feet, are often helpful.

Wearing proper shoes is important. Oversupinators should not wear motion control shoes that limit pronation but, on the contrary, should have flexible, yet cushioned shoes that allow as much pronation as possible. The good news is that these shoes are often light and lively and fun to run in. The shoes should be replaced after a few hundred miles, as shock absorption wears out.

Cyclists may need canting of shoes or pedals, again to distribute the pressures across the foot.

Knowing which athletes are oversupinators will allow adjustments to reduce the injuries most common with this type of foot mechanics. Some of the measures are opposite to what is recommended for overpronators.

Ronald P. Olson

See also Athletic Shoe Selection; Foot Injuries; Orthotics

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Overtraining

Commonly called *staleness* or *burnout,* overtraining syndrome is a potentially serious medical illness experienced by endurance athletes. It is characterized by a decline in athletic performance, fatigue, and emotional changes despite intense physical training. The physiological changes most often seen are reduced exercise time before exhaustion, reduced maximum performance (decreased lactate production and increased anaerobic threshold), and decrease in the maximum heart rate. In females, menstrual changes can be seen. Psychologically, athletes have complaints similar to those seen in depression, including severe fatigue, disturbed sleep, soreness and heaviness of muscles, concentration problems, decreased appetite, generalized depressed mood, and, in males, decreased sexual drive. The etiology is related to an imbalance between training and recovery and is likely multifactorial. The overall prevalence is not known, but it is more commonly seen in males and in athletes trained in endurance sports, such as running, cycling, and multisport events.

Causes

A significant amount of effort and resources have been invested in determining the etiology of overtraining syndrome. Unfortunately, the definitive cause has not been elucidated. We know that repeated intense physical training sessions stress the body and lead to tissue damage. The stress and tissue damage can be reversed with adequate periods of recovery and are often purposely incorporated into training programs because of their beneficial effects. The body has an impressive ability to adapt and regenerate after these episodes of intense exercise, and on recovery, the body has the ability to physiologically adapt to endure higher stress during future training. Unfortunately, for intensely trained individuals, there is a fine line that can be crossed from hard training with adequate recovery to training with inadequate recovery. If this line is crossed, it is called overreaching and is characterized by fatigue and decreased performance. Overreaching can be reversed by a short period of rest for up to 1 to 2 weeks.

Overtraining syndrome is at the extreme end of the continuum, including overreaching. The best evidence suggests that overtraining syndrome arises when there is a prolonged or significant imbalance in this training and recovery interaction. Despite continuing the same level of exercise, or often increased levels of exercise, performance measures decrease. Experts believe that during overtraining syndrome, there is an alteration of the normal chemical messages sent by the brain and glands to the body that signals tissue breakdown rather than the normal tissue regeneration and repair. Therefore, no matter how intense the training is, the body cannot recover and perform at its optimal level. Many athletes misinterpret these early signals, and rather than back off and rest, they further intensify their training. The structures believed to be the most involved are the hypothalamus (brain), pituitary gland (brain), and endocrine glands (which secrete chemicals and hormones). The chemical messengers that have been implicated in this syndrome most often include serotonin, tryptophan, cortisol, adrenaline, growth hormone, and testosterone.

Diagnosis

Diagnosis of overtraining syndrome is often difficult and can be delayed due to the lack of specific criteria and testing currently available. This diagnosis is made clinically and relies on excluding the many other overlapping diagnoses. Evaluation should start with a complete medical history and physical examination by a trained and qualified sports medicine provider. These exams are vital for the physician when making the diagnosis and excluding other causes for the athlete's physical and psychological complaints. Although nonspecific, laboratory evaluations including a complete blood count (for infection and anemia), chemical evaluation (which includes sodium, potassium, kidney function), thyroid studies, iron studies including ferritin (low ferritin represents low body stores of iron and may lead to decreased performance), and tests for infection (mononucleosis, human immunodeficiency virus [HIV] infection, hepatitis) may be performed. Other, more specialized laboratory testing can be ordered based on the individual situation and physician preferences.

Although the hallmark of this diagnosis is decreased performance, with the wide variability in course conditions, competition, and weather, increasing race times are not specific enough for diagnosis of overtraining syndrome. Therefore, currently the best measurement is decreased time to exhaustion and decreased $\dot{V}O_2max$ (measure of the maximum amount of oxygen consumed during activity) during sport-specific exercise, such as time trials or graded exercise testing. Physicians may also order other physiological testing, such as lactate testing (blood tests with exercise) and respiratory testing. A simple, yet nonspecific, physiological test can also be performed at home. Morning pulse readings, taken before arising in the morning, that show 3 to 5 beats elevated beyond an individual normal can be a signal of inadequate recovery, overreaching, or overtraining syndrome.

Treatment and Prevention

Once other causes have been excluded and the diagnosis of overtraining syndrome has been made, the cornerstone of treatment is rest. This treatment plan is often difficult for highly driven athletes to accept, and a great amount of empathy is required when discussing the treatment and return to participation. The length of time required before a structured training program is restarted is variable and ranges from 6 weeks to many months. Athletes will often be more compliant with the prolonged treatment program if light cross-training activities are prescribed. It should be noted that these physical activities should be in a different activity from the athlete's main sport, and all efforts should be focused on maintaining these activities at a nonintense level.

Before the athlete returns to a training program, evaluation of his or her previous level of activity, recovery time, diet, and psychological well-being should be done. Dietary consultation is beneficial for athletes to review their specific individual needs. Consultation with a sports psychologist, both during recovery and during return to sport, can often be useful for the athlete to develop coping skills, reduce stress, and improve mental training skills such as visualization. Furthermore, some athletes will require and respond to the use of antidepressant medications to treat their mood disturbances. Use of these medications is not universally necessary and should be based on a case-by-case evaluation of need.

The best treatment for overreaching and overtraining syndrome is certainly prevention. It is important for athletes and coaches to individualize training programs for all athletes, since all members of the same team or club will invariably have different genetic abilities, base volume of training, and motivation. One of the best keys to prevention is for the athletes to keep a training log. This should include not only daily volume and intensity but also dietary information, major life stressors, and, of significant importance, perceived exertion for each workout. The perceived exertion for each workout may clue the athlete in to a subtle change in training and recovery that may be necessary to prevent injury or overtraining. In the event of a problem, this training log can be beneficial for the sports medicine physician in making a diagnosis and prescribing appropriate treatment.

Jason Diehl

See also Burnout in Sports; Periodization; Principles of Training

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Pain Management in Sports Medicine

For many athletes, pain is an inherent pitfall associated with sports participation. While exertion-related, generalized soreness is a common, self-resolving, and expected result, persistent and localized pain can be an indicator of a more serious underlying injury. Ignoring or masking such signs, which potentially can occur when self-medicating with over-the-counter analgesics, can delay proper diagnosis, lead to worsening of the underlying condition, and ultimately postpone an athlete's return to play. Sports medicine physicians and team members can play a vital role in assessing an athlete's pain and assist in guiding the athlete through a multitude of pharmacologic and nonpharmacologic treatment options, with the ultimate goal of facilitating early functional mobilization and expediting injury rehabilitation.

Pharmacologic Considerations

Acetaminophen

Acetaminophen is frequently suggested as the drug of choice for musculoskeletal pain. Its mechanism of action is not clearly understood. In healthy adults with limb pain, the recommended dosing schedule of 1,000 milligrams (mg) four times a day has been shown in a prospective, double-blind, randomized controlled trial to provide an analgesic effect similar to that of nonsteroidal anti-inflammatory drugs (NSAIDs), with, however, a low adverse effect profile.

Athletes who consume alcohol, have liver conditions, or take additional medications that potentially could cause liver injury should exercise caution when taking acetaminophen. Overdoses can lead to irreversible liver injury and/or death.

Suboptimal pain control with acetaminophen is typically due to medication underdosing. Evidence-based working groups on pain management recommend using acetaminophen as first-line therapy for acute and chronic musculoskeletal pain.

Nonsteroidal Anti-Inflammatory Drugs

NSAIDs are commonly used for the treatment of a wide variety of sports medicine conditions, including pain, soft tissue injuries, fever, and sprains/strains. While the role of NSAIDs in treating pain and inflammation related to rheumatoid arthritis (RA) and osteoarthritis (OA) is better established, the beneficial effects of NSAIDs for common musculoskeletal injuries remain debatable and somewhat inconclusive. Deciding whether or not to use this class of medications should take into consideration underlying medical conditions due to their higher risk profile. Side effects such as exacerbation of asthma and gastrointestinal, kidney, and cardiovascular conditions may be attributed to NSAID use.

The mechanism of action is categorized based on selective versus nonselective blockade of cyclooxygenase. Traditional NSAIDs (e.g., ibuprofen, naproxen, diclofenac, meloxicam, piroxicam) nonselectively block cyclooxygenase-1 and -2

(COX-1 and COX-2, respectively), which typically catalyze the transformation of arachidonic acid to prostaglandin. Blockade of this cyclooxygenase pathway leads to a decreased inflammatory response and ultimately decreased pain. Newer COX-2–specific inhibitors (e.g., celecoxib, valdecoxib) were developed with the goal of sparing gastrointestinal bleeding largely due to the antiplatelet effect of COX-1 inhibition of thromboxane A2. However, thromboxane A2 when unopposed by prostacyclin causes vasoconstriction and platelet aggregation in vascular endothelial cells. This theoretically can lead to clot formation and an increase in cardiovascular adverse events. Several COX-2–specific inhibitors have been removed from the market in recent years due to these cardiovascular concerns; those remaining carry black box warnings regarding their increased cardiovascular risk—potentially fatal ischemic heart disease and stroke.

NSAIDs in sports medicine can be delivered as topical, oral, intramuscular, or intravenous preparations. While the route of delivery is often dictated by the underlying injury or medical condition, in most circumstances a trial of oral NSAIDs prior to more aggressive pain management interventions is considered acceptable practice. Conditions where NSAID use is not generally indicated because they may complicate healing include complete fractures and chronic tendinopathies associated with impingement.

Opioids

Tramadol possesses unique analgesic qualities by acting as a weak, atypical central opioid agonist. Analgesia is produced by binding to mu opioid receptors and weakly inhibiting norepinephrine/serotonin reuptake. Tramadol is proposed to be a preferred choice among opioids due to its superior safety profile and decreased abuse potential when compared with other, stronger opioids. Neurotoxicity, however, is a concern with overdosing. A fixed-dose combination of acetaminophen (325 mg) plus tramadol (37.5 mg) has been shown to deliver better efficacy when compared with either agent alone. Additionally, this combination is better tolerated than tramadol alone or a fixed-dose combination of acetaminophen plus codeine.

Codeine is a prodrug which relies on cytochrome P450 metabolism to morphine for analgesic effect. Ten percent of Caucasian patients are cytochrome P450 deficient, which may explain why it has poor efficacy in certain patients. Codeine is typically available in fixed-dose combination with acetaminophen.

Propoxyphene, like codeine, is typically used in fixed-dose combination with acetaminophen. Like codeine, it has been found to have poor efficacy as an analgesic and to have significant adverse effects.

Hydrocodone is generally considered the most potent oral narcotic used in the treatment of acute musculoskeletal pain. Oxycodone, with or without acetaminophen, appears to have an analgesic effect comparable with that of intramuscular morphine and NSAIDs. Side effects of narcotics include constipation, cardiorespiratory depression, sedation, nausea, and pruritus. Tolerance and physical dependence can occur with chronic use; however, this is generally not a concern in the treatment of acute pain.

Antidepressants

Tricyclic antidepressants (TCAs), in particular amitryptiline, are useful in the treatment of neuropathic pain, low back pain (LBP), and other chronic musculoskeletal pain conditions. *Serotonin and noradrenaline reuptake inhibitors* (e.g., venlafaxine) have similar efficacy to TCAs in providing relief from chronic musculoskeletal pain. *Serotonin selective reuptake inhibitors,* however, have not been promising with regard to pain reduction in musculoskeletal conditions.

Injection Therapy

Injections can play an important role in reducing pain associated with a variety of musculoskeletal injuries. Often, such injections allow an athlete to restore functional range of motion, complete physical therapy, and ultimately regain the strength necessary to escape the cycle of inflammation, pain, and muscular atrophy characteristic of many overuse injuries.

Corticosteroid injections have been used since the 1950s for palliative treatment of inflamed joints, tendon sheaths, and bursae. Common sites of injection include (but aren't limited to) the acromioclavicular joint, intraarticular shoulder, subacromial space, lateral epicondyle of the elbow, greater trochanter of the femur, and intraarticular knee. Care must be taken to limit injections into a weight-bearing joint to no more than three per year. Also, with the understanding that certain tendon injuries have a degenerative (tendinosis/tendinopathy) origin rather than an inflammatory one, the utility of corticosteroid injections for classic tendinitis conditions such as Achilles tendinitis and lateral epicondylitis (tennis elbow) must be reconsidered as corticosteroids may have a deleterious effect in tendinopathies by masking pain that typically results from stimulation of pain receptors by chemicals released from the degrading tissue.

Viscosupplementation, a treatment that involves the injection of high–molecular weight hyaluronic acid into an osteoarthritic joint, has become an option for older athletes who have failed to benefit from conservative pain treatment. Hyaluronic acid is a substance naturally found in synovial fluid and cartilage matrix. It serves as a lubricant, shock absorber, and anti-inflammatory in joints, where it is synthesized by chondrocytes and synovial cells. Treatment cycles typically involve three injections, and cycles can be repeated after 6 months—typically the minimal period for clinical benefit. Although FDA (Food and Drug Administration) approval of hyaluronans is currently limited to the knee, it holds promise as a treatment option for OA of the shoulder, the hip, and several hand/foot joints.

Nonpharmacologic Considerations

Physical activity and exercise have been shown to reduce pain and improve function, particularly in patients with OA, disseminated pain, and chronic LBP. Strategies to encourage adherence are essential to the success of a physical exercise program.

Physical therapy, including manipulation, range of motion, modalities, and massage, can play a significant role in reducing pain and facilitating functional mobilization. Ultrasound is often used as an adjuvant therapy to reduce pain and inflammation in various musculoskeletal conditions. Thermotherapy (e.g., heat wrap therapy for subacute LBP, cold packs for decreasing swelling in knee OA) is an effective, nonpharmacologic alternative for various musculoskeletal injuries. Massage has been effective for LBP relief, particularly when combined with exercise and education.

Transcutaneous electrical nerve stimulation (TENS) is a physical therapy modality that reduces pain by stimulating the peripheral nerves electrically through electrodes placed on the skin surface. TENS has an adjuvant role in the treatment of localized musculoskeletal pain encountered in knee OA, chronic LBP, and RA.

Accupuncture is an effective adjuvant therapy for improving pain and function in the following musculoskeletal conditions: knee OA, chronic LBP and neck pain, shoulder pain, lateral epicondylitis, and RA.

Conclusion

Athletes encounter pain as a result of training, overuse, and traumatic injuries. Many of these injuries can be self-resolving. Athletes commonly use over-the-counter analgesics such as acetaminophen or NSAIDs as the initial treatment of pain and injury. When self-medicating, accurate knowledge regarding effective dosing ranges, intervals, and duration can lead to optimal pain control and avoidance of medication side effects. In some instances, more potent analgesics such as opioids will be necessary; however, the expectation prior to prescribing these agents is that an initial short-course trial of nonnarcotic medication has been attempted. More aggressive therapies such as joint injections depend on the injury's location, the pain severity, and the athlete's level of competition.

The inclusion of nonpharmacologic therapies as part of a multimodal treatment plan is essential to restoring functional mobilization, expediting rehabilitation, and returning athletes as quickly as possible to their sport. The importance of early physical activity in injury rehabilitation cannot be emphasized enough; it remains the cornerstone of a musculoskeletal treatment plan. Involving a sports medicine team comprising physicians, therapists, and additional health professionals can provide an athlete with the tools and resources necessary to return to sports with minimal pain and functional limitation.

Peter Kriz

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Pancreatic Injury

Athletic injuries to the pancreas are relatively rare and most often occur due to trauma to the upper abdomen. The pancreas can also become inflamed (pancreatitis) due to atraumatic causes, which are also worthy of consideration.

Anatomy and Function

The pancreas is an internal organ located in the upper left side of the abdomen. It has a relatively protected position due to the rib cage and spine surrounding it. Pancreatic functions include the production of hormones such as insulin and glucagon (involved in glucose homeostasis) and of pancreatic enzymes to help digest food. It is directly connected to the duodenum (small bowel) and the gall bladder and liver via the bile duct.

Pathology

Pancreatitis that is not due to trauma results from direct digestive enzyme release from injured cells. These pancreatic digestive enzymes cause inflammation in the pancreas and the surrounding region. Involvement of the pancreas can progress with lack of oxygen and obstruction of the pancreatic cells.

Epidemiology

Traumatic injury to the pancreas is unusual and seldom reported. Inflammation of the pancreas, or pancreatitis, has many causes other than traumatic injury. Atraumatic etiologies of acute pancreatitis (predominantly in adults) include

- Gallstones
- Insect or scorpion bites
- Alcohol use
- Procedures such as endoscopic retrograde cholangio-pancreatogram (ERCP)
- Hypercalcemia
- Viral infections
- Hyperlipidemia
- Various drugs
- Hereditary factors

The pancreas is injured in 1% to 2% of abdominal trauma cases, with 10% of abdominal traumas occurring in sports in one historical series in Scandinavia (reported in D. Bergqvist, H. Hedelin, G. Karlsson, B. Lindblad, and T. Mätzsch's 1981 article "Abdominal Trauma During Thirty Years"). It has been suggested that the jarring motions of repetitive activity such as running might result in pancreatic injury, and a low oxygen supply–induced pancreatic pathology has been proposed in the setting of strenuous exercise. Case reports of running-induced diarrhea and other gastrointestinal problems suggest that these disorders result from exercise-related low blood supply to the abdominal organs. Three cases of distance runners who developed an acute abdominal crisis requiring removal of the bowel have been reported. Evidence exists of pancreatitis occurring in surgery patients who underwent periods of low oxygen and blood supply. This supports the conclusion that low oxygen may play a role in the initiation of acute pancreatitis.

Contact/collision sports (e.g., soccer, football, rugby, hockey, karate) seem to have a higher incidence of traumatic pancreatic injury, as do higher-velocity sports (e.g., skiing and snowboarding, cycling) or sports that can result in a fall (e.g., equestrian sports or rock climbing) or being struck by an object (e.g., baseball, lacrosse, track-and-field events).

CT scan of traumatic injury to the pancreas from a sporting event

Source: Courtesy of David Mooney, M.D., Children's Hospital Boston.

Biomechanics

Impact mechanics are important in determining the likelihood of injury. An object or body part (e.g., a foot or knee) striking a localized abdominal segment, such as the upper left quadrant, with a large deceleration or acceleration is the most common mechanism of injury. For instance, a bicycle fall where the handlebar twists and "spears" a child may be the presenting history. In this scenario, the handlebar compresses the pancreas against the spine, resulting in a pancreatic laceration. Body type may influence the risk of injury, as leaner individuals have greater susceptibility because of less fatty abdominal tissue to protect their internal organs from trauma. Acute pancreatitis in the pediatric population primarily results from direct traumatic injury, perhaps in part because most children have such a body type.

The duodenum (small bowel) is very close to the pancreas and is also commonly injured through localized trauma such as the impact from a bicycle handlebar. Bowel perforation (a hole in the bowel) is an important potential coexisting event and also should be included in the initial differential diagnosis as duodenal perforation can mimic acute pancreatitis in many ways.

Clinical Presentation

As with other internal organs, there is often a subtle presentation and minimal physical signs. A high index of suspicion is warranted as catastrophic outcomes (i.e., death) are possible if the symptoms go unrecognized. Patients can develop nausea, vomiting, and abdominal pain up to 48 hours after injury. Typically, the abdominal pain radiates to the back and is central in original localization.

The physical exam technique should follow the traditional medical model of inspection, palpation, percussion, and auscultation. There may be bruising evident in the area of injury on inspection. Lower rib fractures may also be present, hence tenderness to palpation in this location should alert one to potential underlying injury. Serial examination (repeating the exam periodically) of individuals suspected to be at risk for a traumatic event involving the pancreas is necessary. Abdominal tenderness localized centrally, in the left upper quadrant, or more diffuse, increases the suspicion. Rebound tenderness, where pain is provoked by releasing pressure from palpation of the abdomen, is less common. Tapping the abdomen's surface (percussion) can help determine the presence of peritonitis, with an increased note of resonance when intra-abdominal air is present. Auscultation with a stethoscope can elicit bowel sounds unless the bowel has stopped working.

It should be remembered that severe pancreatic contusions and lacerations from a direct injury may confound attempts at clinical diagnosis, as patients often demonstrate minimal blood loss and only subtle signs and symptoms are elucidated. The most common presenting symptoms and signs of trauma to the pancreas are abdominal pain (78.9%; either diffuse or upper abdomen), bowel sounds at initial contact (45.5%), abdominal tenderness (79.5%; most often diffuse), rebound tenderness (9%), and abdominal wall bruising (34.6%).

Investigation

Laboratory blood tests showing elevated levels of the pancreatic enzymes amylase and lipase can alert one to an underlying pancreatic injury; however, the lack of elevation in these blood enzyme levels *does not* rule out pancreatic injury. Serial monitoring may be most appropriate, as elevations in amylase may not occur for hours after injury. Serial monitoring of amylase levels has been suggested in several studies as a means of increasing sensitivity to pancreatic injury. The presence of elevated amylase levels after blunt pancreatic trauma is time dependent, and the elevated serum amylase level may be found in the majority of patients when a specimen is drawn more than 3 hours after injury.

Diagnostic peritoneal lavage (DPL) can improve the ability to diagnose intra-abdominal trauma, and if the criterion of >100,000 erythrocytes (red blood corpuscles) per cubic millimeter is used, then sensitivity is high (96%–100%). DPL is now performed less frequently, perhaps due to the emergence and availability of imaging. It is often perceived as invasive, however, and has a <1% complication rate.

Imaging

Computed tomography (CT) is the most useful imaging modality, though ultrasound is also useful in some circumstances. An ERCP or magnetic resonance retrograde choleopancreatogram (MRCP) may be better for visualizing the pancreatic duct. Contrast-enhanced multislice CT has been regarded as an efficient screening modality for pancreatic trauma.

Focused sonography for abdominal trauma (FAST) is an accepted method for abdominal bleeding screening in athletes with blunt abdominal trauma. Many trauma centers do not have the trained personnel or equipment necessary to use diagnostic abdominal sonography. It has been suggested that the combined DPL and CT screening modalities are a more cost-effective and sensitive pancreatic injury detection method than FAST.

Management

Management decisions have little evidence base due to the rarity of injury to this organ. There are several isolated case reports in the literature. High morbidity (42%) and mortality (16.6%) rates have been reported sometimes when the pancreas is injured in a sports setting. This mortality risk may be related to acute pancreatic duct injury; however, morbidity is associated more with complications.

A common method of describing the severity of pancreatic injury is the Pancreatic Organ Injury Scale (POIS), designed by the American Association for the Surgery of Trauma. Pancreatic injury–related morbidity and mortality are most closely associated with POIS Classes III through V, which involve pancreatic ductal injury.

Treatment is principally supportive, including intravenous hydration, management of electrolyte and metabolic consequences, and pain control. Resting the digestive system and providing nutrition by methods that don't use the gut are accepted.

Complications

Pseudocyst formation is the most frequent complication of acute atraumatic and traumatic pancreatitis. A pseudocyst is a large collection of fluid without a true lining. The clinical course of a traumatic pseudocyst is often lengthy and frequently complicated. Resting the gut, pseudocyst drainage, and procedures to correct the complications of a pseudocyst or pancreatic fistula are required in many cases. Management options include observation to see if the pseudocyst resolves with time, drainage by interventional radiology, and general surgical drainage.

Return to Sports

There are currently no established return-to-play guidelines published in the literature. The physician should rely on the principles of abdominal organ and soft tissue healing to allow anatomic and functional healing. The resolution of all active processes should occur before the athlete is allowed to return to sports in a stepwise fashion. The progress toward return to sports activity typically involves aerobic conditioning, then strengthening, skills practice, contact practice, and scrimmage, followed by competitive return to play if the previous steps have been successfully completed without a recurrence of symptoms.

Hamish Alistair Kerr

See also Abdominal Injuries; Baseball, Injuries in; Field Hockey, Injuries in; Football, Injuries in; Mixed Martial Arts, Injuries in; Rugby Union, Injuries in; Skiing, Injuries in; Snowboarding, Injuries in; Soccer, Injuries in

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Panner Disease

Panner disease was initially described in 1927 by Dr. Hans Jessen Panner, a radiologist, to explain lateral elbow pain in young patients. This diagnosis is unique to the skeletally immature athlete. *Skeletally immature* refers to those who still have the potential for growth of their bones. Panner disease is similar to Legg-Calvé-Perthes disease (often referred to as Perthes disease), which can occur in children's hips and is a necrosis or breakdown of the femoral head, the end of the thighbone that fits into a person's hip socket.

Anatomy

Panner disease is an osteochondrosis of the capitellum involving the entire ossific nucleus (the growth center). *Osteochondrosis* refers to the necrosis or breakdown of growth centers in the pediatric or skeletally immature patient followed by regeneration or healing. The growth centers are important because they are responsible for growth of the bones, in this case the growth of the humerus, or long bone of the upper arm. The growth centers at the end of the humerus are responsible for 20% of the final limb length of the upper arm. Thus, injury can result in abnormal growth and decreased length of the arm. The capitellum is the lateral humeral condyle, which is the rounded portion at the end of the humerus. The capitellum articulates with the radial head (one of the forearm bones). The articulation of the capitellum and the radius contributes to movement at the elbow. Simply stated, Panner disease involves the breakdown and then healing of the growth center at the end of the humerus on the lateral (outside) portion. It is the most common cause of chronic lateral elbow pain in athletes under age 10.

Panner disease should be differentiated from osteochondritis dissecans (OCD) of the capitellum, which occurs in an older pediatric population, usually ages 11 to 16, and only involves a portion of the growth center. It is also not characterized by the classic regeneration and recalcification seen in Panner disease. It has the potential for more long-term complications, unlike Panner disease, which is generally a self-limiting condition.

Causes

With increasing participation and an emphasis on excellence at a young age, injuries are becoming more prevalent in the younger population. Often, kids are now participating year-round in only one sport. This does not allow for any rest time and results in an increased incidence of injuries, especially the overuse-type injuries. As described above, the presence of open growth plates represents a unique situation and opportunity for different injuries to occur compared with those seen in the adult or skeletally mature population.

Panner disease is one example of an overuse-type injury. It occurs due to repetitive axial loading or lateral compression of the elbow during activities such as gymnastics and baseball throwing, respectively. During pitching, especially the early- and late-cocking as well as early-acceleration phases, the lateral portion of the elbow experiences large compressive forces. With repetition, these forces can lead to abnormalities in the radiocapitellar articulation, such as Panner disease, in the young athlete. Gymnasts spend a lot of time using their upper extremities as weight-bearing joints. It is thought that this repetitive axial loading is responsible for injury to the lateral elbow growth center in these athletes.

Signs and Symptoms

Panner disease is typically seen in the younger athlete, ages 5 to 10, and more commonly in boys.

Children usually present with dull, achy lateral elbow pain and subjective stiffness, most always involving the dominant upper extremity. Throwing athletes will complain of pain with throwing or a decrease in their throwing speed. The pain usually resolves with rest. It can be due to an acute traumatic event; however, as mentioned above, it is more commonly due to overuse. On physical exam, patients may have decreased ability to fully extend their arm. This is due to a flexion contracture from an abnormal amount of joint fluid in the elbow, known as an effusion, or from stiffness at the elbow from not moving it due to the pain. They may also have tenderness to palpation on the lateral portion of their elbow.

In differentiating Panner disease from an OCD lesion of the capitellum, clues in the history and physical exam involve the age of the patient and a history of catching or locking of the elbow joint. As stated, Panner disease typically occurs in those younger than age 10, whereas OCD is found in the older pediatric patient. OCD is also associated with loose bodies in the elbow joint that can cause catching or locking, while Panner disease is not. A loose body represents a piece of the end of the bone or the articular cartilage that has broken loose and is free to move around within the joint.

Diagnosis and Treatment

X-rays are used to diagnose this condition. Elbow X-rays will show fragmentation of the capitellar growth center. Comparison views of the contralateral elbow are needed to help make the diagnosis. The natural history of Panner disease involves a self-limited, benign condition. Therefore, treatment is focused on conservative, nonsurgical measures. It involves activity modification (i.e., avoiding activities that produce discomfort), anti-inflammatory medications (such as ibuprofen), and ice. If there is decreased range of motion of the elbow, the patient may be referred to a physical therapist, or a home exercise program that focuses on regaining motion may be prescribed. If the pain is severe, an arm sling or posterior splint may be temporarily recommended. Most symptoms will improve over 3 to 4 weeks, but complete recovery can take up to 3 years. X-rays should be taken intermittently to assess healing. To date, there is no consistent evidence to suggest any long-term sequelae, but some studies do show permanent deformity within the joint.

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Patellar Dislocation

Patellar dislocation is an acute injury where the patella (kneecap) fully dislocates or slides out of its groove on the femur. Patellar dislocation can occur with minor trauma in those with certain anatomical variations that predispose them to this condition. Patellar dislocation can also occur with direct trauma or a sudden change in direction. Patients will sometimes report hearing a pop and will often have rapid swelling and difficulty with any knee flexion.

Anatomy

The patella, or kneecap, is a thick triangular piece of bone that covers and protects the knee joint. It lies within a vertical groove on the femur (thighbone). This vertical groove is called the trochlear groove and is located between the medial and lateral femoral condyles. The condyles are two bulbous ends of the femur through which our weight passes. The patella is covered by a fibrous capsule and is attached above to the tendon of the quadriceps femoris (the main extensor muscle on the front of the thigh). It is attached below to the patellar tendon, which then connects to the tibial tuberosity (an oblong elevation of the tibia).

The quadriceps muscle group consists of the vastus lateralis (outer portion of the thigh muscle), vastus medialis (inner portion of the thigh muscle), and vastus intermedius (middle portion of the thigh muscle), which originate on the femoral shaft and have muscle tendons that insert on the superior (upper) pole of the patella.

The medial patellofemoral ligament (MPFL) originates at the medial femoral condyle on the inner aspect of the knee and attaches to the medial (inside) border of the patella. The MPFL has been found to be the major soft tissue restraint to lateral patellar dislocation (kneecap dislocating to the outside of the knee). The MPFL and two other ligaments comprise the medial patellar retinaculum.

The lateral aspect of the patella is stabilized by the lateral patellar retinaculum. The lateral patellar retinaculum is the confluence of several fibrous structures, including the lateral patellofemoral ligament (LPFL), which connects from the lateral femoral condyle to the outer portion of the patella.

Causes

Patellar dislocation can result from minor trauma in those with risk factors or can result from a high-impact force in a patient with normal anatomy. A common mechanism is dislocation of the right patella when the torso rotates left and the right foot is planted on the ground. The patella then dislocates laterally (to the outside of the knee). Lateral instability is much more common than medial instability. Risk factors for patellar dislocation include the following:

- Any abnormality that increases the lateral (outside) force on the patella
- Weakness of the vastus medialis muscle
- Hypertrophy of the vastus lateralis muscle, thus pulling the patella laterally
- Patella alta—an abnormally high-riding patella with a long patellar tendon
- Shallow trochlear groove, which makes it easier for the patella to slide out of this groove
- Foot pronation, where the foot turns outward at the ankle, causing walking to be done on the inner side of the foot
- Pes planus, or flat feet
- Genu valgum, also called “knock-knees,” where the knees angle inward and the lower legs angle outward
- Femoral anteversion, where the femoral neck (the top of the femur near the hip joint) leans forward with respect to the rest of the femur, causing the knees to rotate inward
- External tibial torsion, where the tibia is rotated outward

Symptoms

An acute patellar dislocation often occurs after direct contact or a sudden change in direction. Symptoms include rapid swelling of the knee joint, intense knee pain, and inability to extend the knee joint. Sometimes patients will report having heard a pop when the injury occurred. The knee is usually maintained in a flexed position. Patients who have had one episode of dislocation are more likely to have another because the tissues have been stretched out by the initial episode. Such patients usually have some of the anatomic predisposing factors listed above.

Symptoms may also manifest as a slow progression of pain located at the front of the knee (anterior). This type of pain is exacerbated with physical activity including using the stairs, squatting, or prolonged sitting. These activities can cause lateral tracking of the patella on the trochlear groove.

Diagnosis

Diagnosis begins with taking a complete history, including asking questions about the mechanism of injury. A physical exam is the next step. The examiner begins with inspection of the knee. With acute patellar dislocation, a knee effusion is often noted. If the patella is still dislocated at the time of inspection, the normal anatomy of the knee joint will be disturbed, and one can palpate the patella off to the side of the knee. The knee may be kept in flexion. Range of motion may be limited in both flexion and extension. There may be tenderness along the medial (inner) edge of the patella if the medial retinaculum has been torn. If the MPFL has been torn, there will be tenderness near the medial femoral epicondyle. Patients may demonstrate apprehension or anxiety at any attempts to manipulate or maneuver the patella. This is called the "apprehension sign." The examiner should also check for signs of malalignment, including genu valgum, pronation, and femoral anteversion. One can also assess for abnormal lateral tracking of the patella during extension (called a *positive J sign*).

Plain radiography is the most common diagnostic test used for patellar dislocation. Anteroposterior, lateral, and sunrise or axial views are used to demonstrate the location of the patella. The axial or sunrise view shows the relationship of the patella to the trochlear groove of the femur. This view can demonstrate the presence of a dislocation. A lateral radiograph can be used to demonstrate patella alta or patellar tilt. Plain radiography can also reveal patellar, femoral, or tibial fractures. Computed tomography (CT) scanning may be more sensitive in depicting the relationship between the patella and the trochlear groove. Magnetic resonance imaging (MRI) can be used to identify soft tissue anomalies if no bony anomalies are found with plain radiography or CT. MRI can be very helpful in evaluating the patellar cartilage and other soft tissue structures surrounding the patella.

Treatment

Nonsurgical

In some patients, the patella may spontaneously reduce with leg extension. In others, manual reduction may be required. This involves applying gentle medial force to the patella while extending the knee. Immediately after the injury, management includes the PRICE principle: *p*rotection of the injured joint, *r*est, *i*ce, *c*ompression, and *e*levation to control swelling. It has been shown that a period of immobility may be helpful during the acute phase. Many patients use a posterior splint with the knee in extension to approximate and heal the disrupted medial structures. During the acute phase, most physicians will limit weight bearing or recommend partial weight bearing. The athlete is then started on a program of static exercises to strengthen the quadriceps muscles, initially with the splint on. The duration of immobilization varies but usually does not exceed 6 weeks. This will prevent atrophy of the muscles surrounding the knee joint. Physical therapy involves strengthening the quadriceps muscle group and stretching the hamstrings. An elastic brace with lateral reinforcement can be used when the athlete returns to physical activity to prevent lateral tracking of the patella. This brace is called a *lateral buttress brace.*

Surgical

Surgical intervention is usually reserved for those in whom the dislocation was traumatic with associated fractures or in those who experience recurrent dislocation and instability. After an acute dislocation, cartilaginous injuries can occur to the patella or lateral femoral condyle. Knee arthroscopy can repair or remove the fracture fragments. Arthroscopy is an operation that involves inserting a small fiberoptic TV camera into the knee joint to visualize the structures inside the joint. Arthroscopy may also be indicated when conservative management is not effective and the athlete experiences symptoms that indicate the presence of a loose body—such as locking or catching or persistent knee pain.

Procedures can be classified into soft tissue and bony procedures. Soft tissue procedures include medial repair and lateral release. Reconstructing the medial (those inside the knee) structures may provide a restraint to lateral dislocation. Often the medial retinaculum and/or the MPFL is repaired. Lateral release involves making an incision in the lateral retinaculum to reduce the pull of this fibrous cartilage on the patella. Dislocation of the patella medially is almost always due to a lateral release that has been extended too far. The most common bony procedure is a tibial tuberosity transfer. This involves moving the tibial tuberosity more medially to maintain better alignment of the patella in the trochlear groove. Often, surgery involves a combination of these procedures.

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Patellar Tendinitis

Patellar tendinitis is an overuse injury involving the tendon between the patella and the tibia (the patellar tendon). The patellar tendon is the attachment of the quadriceps muscle to the tibia. The role of the quadriceps, and therefore the role of the tendon, is to extend the knee. Aggravation of the patellar tendon is a common source of pain. This is caused by repetitive trauma to the tendon, frequently associated with jumping, kicking, or running. The process of injury is usually a repetitive microtrauma with acceleration and deceleration (as occurs with jumping and landing) and extrinsic loading of the tendon. The individual forces cause only slight injury, but there are not adequate periods of rest for the tendon to heal. The process of repeated microtrauma leading to the development of tendinitis is similar to the process leading to stress fractures. Because it occurs frequently under the repetitive loading of jumping, patellar tendinitis is frequently referred to as jumper's knee.

The name *tendinitis* suggests that it is the result of an inflammatory process; however, pathologically there is usually little or no evidence of acute inflammation. Pathologic evaluation reveals a mucoid substance separating the collagen bundles. There may also be evidence of microscopic or partial tearing of the tendon. These findings are consistent with degenerative change. Regenerative changes may also be seen, including increased cellularity and neovascularization—the growth of small blood vessels throughout the tendon. Because of this, other terms commonly used for this condition are patellar *tendinosis* and *tendinopathy*, which suggest a degenerative change or any abnormality of the tendon instead of only inflammation (Figure 1).

Clinically affected individuals complain of pain over the tendon. This usually is noticed as a progression of symptoms over days or weeks. Occasionally, there may be a more rapid onset of pain with one step or jump. The most common location of pain is the proximal portion of the tendon just beneath the patella.

In the early stages, the pain is present only after a hard activity or workout. It may be noticed at the beginning of the activity and may diminish after a warm-up. The pain will then progress to last longer. It will last through the entire workout and then occur during other periods of activity throughout the day. Again, activities that load the tendon will tend to be the most painful. This includes going up or down the stairs, squatting, kneeling, and lifting or carrying weight. If left untreated, the condition will progress to a painful state even at rest. The following table classifies patellar tendinopathy according to four grades:

Grade I	Pain after activity
Grade II	Pain before and after activity
Grade III	Pain causing restriction of activity
Grade IV	Pain during activities of daily living

There are multiple intrinsic and extrinsic factors that may predispose one to patellar tendinosis. Intrinsic factors include knee alignment, hamstring, and quadriceps tightness, core hip and girdle strength, and motion of the ankle and knee. Any restriction of complete ankle or knee motion may increase the force across the patellar tendon at impact. Excessive pronation or excessive fast pronation (with a neutral foot) will create excessive force on the patellar tendon. Finally, a rigid cavus foot may also predispose to patellar tendinosis. Extrinsic factors include the magnitude of the force, the duration of the force, and the angle of the knee when maximal stress is applied. Harder playing surfaces, such as concrete, transmit a greater force than softer surfaces, such as grass. A longer workout will increase the total duration of the impact. Impact with the knee in a flexed position, as occurs when running uphill or lunging, creates greater stress along the patellar tendon.

Examination

Evaluation for patellar tendinosis should include evaluation for intrinsic factors that may predispose the development or prolongation of the tendinosis. This should include assessment of alignment of the foot and knee, flexibility, and strength. Evaluation of the patellar tendon should be done with the individual in a supine position with the knee straight. The patellar tendon will most frequently be tender to palpation at the inferior pole of the patella. Then with the knee flexed, pulling the patellar tendon tight, the tenderness will be decreased. There may be notable atrophy of the quadriceps. The affected and unaffected sides should be compared for flexibility of the hamstring and quadriceps. The iliotibial band (ITB) should be checked for flexibility, again comparing with the unaffected side. Knee effusion is rarely present with an isolated patellar tendinosis and indicates that there is likely a coexisting injury.

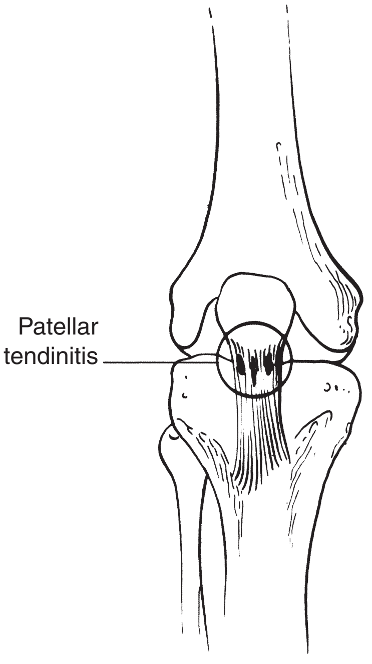

Figure 1 Patellar Tendinitis

Patellar tendinitis should involve only the patellar tendon. If there is bony tenderness over the tibial tuberosity or the inferior pole of the patella in a skeletally immature individual, it may indicate either Sinding-Larsen-Johansson syndrome or Osgood-Schlatter syndrome.

Radiographic Findings

The diagnosis is generally made clinically, so X-rays are not usually necessary but can be useful to rule out other diagnoses. In the case of Sinding-Larsen-Johansson syndrome, the inferior pole of the patella may have decalcification or fragmentation, which will be noted on the radiograph. The patellar tendon is not visualized on plain radiographs; however, the diagnosis can be confirmed with magnetic resonance imaging (MRI) or ultrasound. On an MRI scan, there is typically evidence of inflammation or swelling within the tendon. Ultrasound may show thickening of the tendon, a focal tear, or the presence of neovascularization (new blood vessel formation within the tendon).

Treatment

Conservative treatment consisting of rest, ice, and anti-inflammatory medications is the standard of care. Initial treatment should begin with rest. Complete rest should be considered if possible with higher-grade (III or IV) injuries. Relative rest may be an option with lower-grade injuries. Relative rest will include a decrease in the activity that is triggering the injury. Therefore, sprinting and jumping activities as well as weight lifting involving knee extension should all be eliminated or severely limited. Ice application after activity will help reduce pain and acute inflammation. Use of nonsteroidal anti-inflammatory medications (NSAIDs) is somewhat controversial since the disease process is not inflammatory; however, NSAIDs are useful to control pain. Physical therapy modalities including ultrasound and iontophoresis may also help with pain modulation. Ultrasound has been shown to increase collagen synthesis in surgically severed animal tendons and may play a role in stimulating tendon repair in tendinosis.

The use of a counterforce patellar tendon strap will decrease pain with activity. This is a simple strap that is worn around the lower leg so that it places force on the mid portion of the patellar tendon. This distributes the force away from the injured portion of the tendon. This strap only needs to be worn during activity.

Biomechanical correction is required to allow for healing and to prevent reinjury. This includes increasing the flexibility of the calf, hamstrings, quadriceps, and ITB; correction of excessive pronation with the use of orthotics; as well as core strengthening. These corrections will decrease future stress on the tendon.

Finally, emphasis should be placed on progressive strengthening of the patellar tendon and quadriceps.

In cases of severe tendinosis, more invasive therapies may be considered. Although steroid injection of the tendon is not recommended, recently the use of prolotherapy injections to the tendon to promote a healing response has been considered. In extreme cases, or cases not responsive to the above measures, surgery may be considered. Surgical treatment consists of debridement of the diseased portion of the tendon. Surgical outcomes are not perfect, and only about 50% of surgical patients are able to return to their previous level of competition.

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See also Osgood-Schlatter Disease; Patellofemoral Pain Syndrome; Tendinopathy

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Patellofemoral Pain Syndrome

Anterior knee pain is one of the most common clinical complaints in all age-groups. It may affect as many as 25% of all athletes. Patellofemoral pain is more common in women than in men. The symptoms are pain, instability, or a combination of the two. Instability ranges from mild maltracking to gross patellofemoral dislocation. It may present as an acute or chronic condition.

Anatomy

Soft Tissue Elements

Active Restraints of the Kneecap

The *quadriceps muscle* holds the kneecap in the intercondylar notch. The four components of the quadriceps muscle are the rectus femoris, the vastus lateralis, the vastus intermedius, and the vastus medialis. The most medial one is the vastus medialis obliquus (VMO).

The VMO has distinct fibers in the distal third of the vastus medialis. The VMO is located medial to and is innervated separately from the group. It inserts at an angle of 55° to 65° and counteracts the normal laterally directed pull on the patella. The outside aspect of the quadriceps is the vastus lateralis obliquus (VLO). It is a component of the vastus lateralis. The fibers of the VLO insert at an angle of 38° to 48°, while the vastus lateralis inserts at an angle of 12° to 15°. The VLO provides a direct lateral pull.

Passive Restraints of the Kneecap

The *patellar tendon* limits patellar movement away from the tibia. It articulates with the trochlea in deep flexion to increase the contact area of the kneecap.

The *lateral retinaculum* tethers the patella to the iliotibial band, the lateral femur, and the tibia. It is stronger than its medial counterpart. The fibers of the lateral retinaculum can be divided into the superficial oblique lateral retinaculum, the deep lateral retinaculum (which is the primary restraint), the proximal epicondylo-patellar band, the distal patello-tibial band (which extends below the lateral joint line), and the deep transverse retinaculum.

The medial soft tissue restraints contain the *medial patellofemoral ligament.* This is a capsular thickening arising from the adductor tubercle and inserts into the posterior, superior two thirds of the medial border of the patella. It has its maximal tension at 30° of knee flexion and serves as the major medial soft tissue restraint to lateral displacement (53%). Other parts of the medial restraint are the *patello-tibial ligament* (22% restraint), the *patello-meniscal ligament,* and the *medial retinaculum.*

Bony Elements

The Kneecap/Patella

The patella is the largest sesamoid bone in the body. The kneecap has seven facets—three lateral (concave) and three medial (flat or convex) facets separated by a median ridge. A medial odd facet articulates only in extremes of knee flexion. The retropatellar articular cartilage is up to 7 millimeters thick, the thickest in the body. It is free of nerve endings, more permeable, and more pliable than other articular cartilage. The cartilage has a different contour from the underlying bone.

The Femoral Trochlea

The femoral trochlea can be divided into medial and lateral facets and the supratrochlear fossa. It is shallow at its proximal extent and deeper distally. The lateral facet predominates, is stronger and taller, and has a greater radius. In comparison, the cartilage of the femoral trochlea is significantly thinner than that of the patella.

Motion

The patella serves as a fulcrum and increases the moment arm of the quadriceps by transmitting force at a greater distance from the axis of rotation. The efficiency of the extensor mechanism is increased 1.5 times. This increases the moment arm of the quadriceps by 30% near extension and 15% at 30° of flexion. This raises the efficiency of the extensor mechanism by 1.5 times.

Contact between the patella and the femur is initiated at 10° degrees of flexion. From 0° to 90°, the contact area of the patella shifts from distally to proximally.

Patellofemoral Compressive Forces

The compression forces that work on the patella depend on the activity. Walking leads to compression forces of half the body weight, while climbing stairs leads to forces 3.3 times the body weight. The contact area between the patella and the femur increases from 0° to 60° of flexion. At 60° and higher, there are variable contact area changes. The contact area increases with increasing quadriceps force as a result of articular surface changes.

As the knee flexes from full extension, contact between the patella and the femur progresses from distal to proximal along the patella as forces within the patellar tendon diminish relative to forces in the quad tendon. In full extension, the patella lies at the upper end of the trochlea, and the median patellar ridge lies lateral to the center of the trochlea.

At 10° to 15° flexion, the patella is centered in the trochlea with distal patellar articulation in early flexion.

The quadriceps forces increase dramatically at 90° of flexion, which also increases the articular contact forces.

Beyond 90°, the trochlea articulates with the proximal patella, and the medial facet articulates with the medial femoral condyle.

Patellofemoral Trauma

Patellar Fractures

Transverse fractures are the predominant presentation (50%–80%), secondary to an indirect force. A longitudinal, stellate, or comminuted fracture is usually the result of a direct blow.

The usual treatment for these is open reduction and internal fixation (ORIF), nonoperative treatment, or patellectomy.

Patellar Stress Fractures

Patellar stress fractures are a rare overuse injury. The literature reports occurrence of this injury in endurance runners, volleyball players, basketball players, fencers, and high jumpers. Two types, a longitudinal and a transverse pattern, have been described. If the diagnosis is delayed, a surgical solution is indicated.

Quadriceps Tendon Rupture

The quadriceps tendon rupture is an injury that occurs in patients older than 40 years. X-rays show a low patella position. In case of a complete tear, early operative intervention is necessary.

Patellar Tendon Rupture

The patellar tendon can also rupture. This is also an injury that usually occurs in athletes age 40 years and older. The most common site is the inferior pole of the kneecap. It may be associated with a history of patellar tendinitis. Early surgical repair is the preferred treatment.

Nontraumatic Patellofemoral Pain

Patellar Tendinosis or "Jumper's Knee"

As a result of repetitive microtrauma, as occurs in running, jumping, and kicking sports, an athlete can develop tenderness, usually on the inferior pole of the patella. This tendinosis is classified into grades:

In Grade I tendinosis, pain is perceived only after activity. In Grade II tendinosis, pain is experienced with activity, but it does not interfere with participation. In Grade III tendinosis, pain occurs during and after participation. This time it interferes with competition.

Treatment

Treatment for Grades I and II includes activity modification, stretching, ice, and anti-inflammatory medication. Grade III requires the same treatment as Grades I and II. In addition, cessation of sports is required. If symptoms persist, surgical debridement may be indicated.

Plica Syndrome

The medial synovial plica is the most common location. If this syndrome is present, the lateral and suprapatellar plica can also cause symptoms. Plicas can become symptomatic after repetitive trauma. Inflammation and impingement on the medial femoral condyle can be found. The plica can often be palpated over the medial femoral condyle with passive flexion and extension.

Treatment

A symptomatic plica syndrome is first treated conservatively (with anti-inflammatory medication, quads exercises, and steroid injection). Should symptoms persist, arthroscopic excision may be indicated.

Chondromalacia

Chondromalacia refers to structural damage of the articular cartilage. It is classified into four groups. Group I shows softening of the articular cartilage. Group II has chondral fibrillation or fissuring. In Group III, the chondral fibrillation has fissuring that extends to the subchondral bone. Group IV is characterized by exposed subchondral bone. Chondromalacia may be idiopathic but is usually secondary to malalignment or instability.

Treatment

Treatment options are complex and depend on alignment issues and lesion location.

Osteochondritis dissecans (OCD)

Osteochondritis dissecans (OCD) lesions have been reported in both the patella and the femoral trochlea. They are characterized by cartilage and adjacent subchondral bone detaching from the bony bed. The most common complaints are pain and swelling. OCD is typically found in teenage athletes. Healing may occur in the skeletally immature with 6 to 12 weeks of immobilization. Computed tomography (CT) or magnetic resonance imaging (MRI) can help with the diagnosis. Unfortunately, the healing rate of patellar or trochlear OCD is lower than that of OCD in its more typical location on the medial femoral condyle.

Treatment

An OCD lesion can be found incidentally. In this case, and when the patient is asymptomatic, observation is indicated. If the loose segment is small, surgical removal may be indicated. If the fragment is large, fixation with screws or bioabsorbable pins is the treatment of choice.

Dorsal Defect of the Patella

In general, this is a benign lesion containing nonspecific fibrous tissue. It is located along the superolateral aspect of the articular surface of the patella. Radiographically, a radiolucency with sclerotic margins and intact overlying articular cartilage can be found. This frequently heals spontaneously by sclerosis.

Bipartite Patella

A bipartite patella describes an ununited ossification center and usually involves the superolateral corner of the patella. The symptomatic area can be excised if symptoms persist.

Chronic Regional Pain Syndrome (CRPS)

Chronic regional pain syndrome (CRPS) is characterized by severe pain out of proportion to the physical findings, delayed recovery after the injury, vasomotor disturbances, and trophic changes. Up to 30% of CRPS patients have had an arthroscopy in the past.

Treatment

If diagnosed within 6 weeks, conservative treatments are indicated. These include anti-inflammatory medication, physical therapy, weight bearing, and contrast baths. If symptoms persist beyond 6 weeks, a sympathetic blockade or new, stronger medications may be indicated. This can be a very difficult problem to treat.

Intraosseous Hypertension of the Patella

This is a controversial diagnosis. If the intraoperative intraosseus pressure is higher than 90 mmHg (millimeters of mercury pressure), a core decompression to lower the pressure is indicated.

Patellofemoral Malalignment

Normal Patellofemoral Position

Almost always, an underlying malalignment problem and/or a tight lateral retinaculum are the cause for patellofemoral pain in this variant. Ligamentous laxity of the knee, particularly anterior cruciate ligament laxity, can be the culprit. If the patella is normally positioned (no alta/baja), a realignment procedure itself will usually correct the problem. If chondrosis/arthrosis is also present, an anterior transfer of anterior tibial tuberosity to decompress forces may be required.

Abnormal Patellofemoral Position

An existing problem such as patella alta/baja associated with lateral subluxation needs to be assessed. This may require a three-dimensional tuberosity shift.

Medial Patellar Subluxation/Dislocation

This condition is usually iatrogenic, secondary to realignment procedures. It can be associated with internal tibial torsion or paralysis (polio). Surgical correction is difficult. Ancillary information including MRI, CT, and femoral nerve stimulation for dynamic tracking should be maximized.

Nonoperative Treatment

This is historically the cornerstone of treatment for patellofemoral disorders. Rehabilitative goals are symptom reduction and improvement in strength and endurance. Each program needs to be individualized to meet the patients' needs. Patients need to understand that symptoms may wax and wane regardless of the mode of treatment (i.e., operative or nonoperative).

Strengthening

Short Arc Quad Exercises

Short arc quad exercises are intended to help use low contact pressures at 0° to 30° flexion. They claim to better isolate the VMO. Whether the exercises are better in open chain or in closed chain is being debated. Some reports indicate that closed-chain exercises are superior.

Isokinetic Exercises

Isokinetic exercises are less appropriate due to the significant risk of overloading the cartilage, especially in eccentric contractions.

Pelvic Position

An anterior pelvic position and internal femoral rotation are detrimental for the knee. Therefore, strengthening of the hip extensors and hip abductors, in addition to reducing postural habits that cause anterior pelvic tilt, may help reduce patellofemoral pain.

The advent of dynamic MRI introduced a new component to the diagnosis and treatment. For the first time, it was possible to show the femur internally rotating under the patella. This led to reconsideration of many traditional rehabilitation protocols. In this case, the focus is now more on hip external rotation and abduction strengthening, in combination with core strengthening.

Bracing and Taping

The use of a brace or athletic taping may reduce instability symptoms. As a specific type of taping, McConnell taping serves as an adjunct to the rehabilitative strengthening program. These measures may provide immediate relief, thereby increasing effective training.

Correcting Foot Deformities

If a concurrent foot deformity is found, the use of corrective orthotics may be beneficial to the knee as well.

Operative Treatment

Procedures intended to correct malalignment can be divided into five categories:

1. Release of tight lateral retinaculum
2. Proximal realignment of the extensor mechanism
3. Distal realignment of the extensor mechanism
4. Combined proximal and distal realignment
5. Articular cartilage procedures

Lateral Retinaculum Release

This is done alone or with other realignment procedures. Current indications are based on the medical literature. They include patellofemoral pain with lateral tilt, lateral retinacular pain with lateral tilt or lateral patellar position, and tight lateral retinaculum leading to an excessive lateral pressure syndrome.

Contraindications for this procedure include advanced patellofemoral arthritis, normal patellar tracking, and significant subluxation or dislocation. In the case of dislocation, a medial soft tissue procedure or distal realignment procedure is often needed in addition to the lateral release.

Proximal Realignment Procedures

These procedures are indicated for recurrent patellar instability with evidence of lateral patellar translation or displacement and deficient medial restraints (increased lateral glide on exam). These procedures have the advantage of avoiding contact with the femoral and tibial growth plates in the skeletally immature and may help re-create a more normal anatomy.

Distal Realignment Procedures

Several different techniques of tibial tubercle displacement have been reported. These include a posteromedial, medial, anterior, anteromedial, distal, proximal, and three-dimensional shift. Indications for these more complex operations include persistent patellofemoral pain related to malalignment, lateral facet arthritis and excessive Q angle, and a failed lateral release.

Soft Tissue Distal Realignment in the Skeletally Immature

An injury to the anterior proximal tibial physis may lead to a recurvatum deformity. Procedures such as the Galleazzi procedure or Roux-Goldwaithe are commonly performed in combination with other realignment procedures.

Surgical Treatment of Cartilage Arthrosis

The orthopedic surgeon has several intervention choices.

Cartilage debridement may help with mechanical symptoms. Intact cartilage is left alone. An intraoperative lavage alone may reduce pain.

Subchondral bone perforation, also called microfracture, encourages fibrocartilaginous ingrowth. The realignment procedures have been discussed above already.

With advanced patellofemoral arthritis, *patellar resurfacing* has not been shown to provide good results, but this may be due to the prosthesis chosen. The indications for this procedure are unclear at this time.

Patellofemoral arthroplasty has the theoretical benefit of replacing both surfaces. This intervention may have problems with component loosening. Efforts to improve this technique are continuing.

Total knee replacement may seem a drastic approach, although some studies describe its indication for isolated advanced patellofemoral arthritis. The outcome has been better than the outcome of patellofemoral replacement, isolated debridement, or patellectomy.

Patellectomy, or removal of the kneecap, is considered by many surgeons as the last resort. Some surgeons describe up to 90% excellent results. The indication for this procedure is severe patellofemoral arthritis and failed realignment procedures. Patellectomy may be combined with a distal realignment procedure to improve quadriceps efficiency.

A femoral trochlea plasty would be indicated for trochlea dysplasia. It consists of elevation of the lateral facet of the femoral trochlea and grafting.

Risk Factors for Patellofemoral Pain

The risk factors for patellofemoral pain can be classified as follows:

- Altered pH of the damaged tissues
- Avascular necrosis, patella
- Barometric pressure changes
- Bipartate/multipartate patella
- Chondromalacia
- Cytokines release
- Decreased explosive strength
- Excessive lateral pressure (syndrome)
- Fat pad impingement
- Fibroneuromatous degeneration of the lateral retinaculum
- Flexor hallucis entrapment
- Hallux rigidus
- Hypermobile patella
- Increased osseous metabolic activity
    - Loss of tissue homeostasis
- Intra-osseous hypertension
- Lateral retinacular neuromata
- Miserable malalignment (lower extremity)
    - Femoral anteversion
    - External tibial torsion
    - Pes planus/hyperpronation
- Muscle imbalance of quadriceps
    - Rectus femoris and VMO
    - Impingement of fat pad and medial retinaculum
- Neoplasm
    - Osteoid osteoma
    - Hemangiomata
- Non-RSD (Reflex Sympathetic Dystrophy) sympathetically mediated pain
- Osgood-Schlatter disease
- Overuse
- Patellar hypermobility
    - Patellar tilt
    - Patellar subluxation
- Patellar instability
- Patellar tendinitis
- Patellofemoral malalignment
- Pelvic instability
    - Core instability
- Peripatellar synovitis
- Plica syndrome
- Psychosomatic syndrome
    - Depression, anxiety, and aggression
    - Past history of physical or sexual abuse as a child
- Quadriceps tendinitis
- Referred pain from hip/spine
- Retinacular ischemia from vascular torsion
    - Secondary to patellofemoral malalignment
    - Producing neural growth factor
- RSD
- Saphenous nerve entrapment
- Sinding-Larsen-Johansson disease
- Slow VMO reaction response time
- Stress fracture patella
- Synovial impingement
- Tight gastrocnemius
- Tight hamstrings
- Tight quadriceps
- Venous engorgement

Marc P. Hilgers

See also Chondromalacia Patella; Knee Injuries; Patellar Tendinitis; Sports Injuries, Overuse

Further Readings

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Pectoralis Strain

In recent years, pectoralis strain, once rarely seen, has become increasingly common owing to the increasing number of high-performance athletes and the greater priority given to intensive weight training. This injury occurs almost exclusively in males between the ages of 20 and 50. It usually pertains to the pectoralis major muscle, a highly visible muscle with immense strength located at the front of the chest. *Strain* means stretching the muscle too far; a severe strain can often lead to tearing of the muscle fibers (sometimes even the entire muscle from its attachment). Pectoralis strain can refer to a partial rupture of the muscle, although it is usually associated with complete rupture all the way to the bone. A pectoralis strain can be a potential threat to the career of an athlete and should be handled promptly and properly.

Anatomy

The term *pectoralis strain* most commonly means a strain or tearing of the muscle's point of insertion. The pectoralis major muscle is a fan-shaped muscle and has three heads arising from its three sites of origin:

1. *Clavicular head:* It takes origin from the medial half of the clavicle, that is, from the inner half of the collar bone.
2. *Sternal head:* It has two parts, upper and lower. The upper part arises from the manubrium, the upper body of the sternum (the central bone in the chest), and the second to fourth ribs, that is, from the upper frontal part of the chest. The lower part arises from the distal body of the sternum as well as the fifth and sixth ribs, that is, from the lower part of the chest. Basically, the pectoralis major muscle encloses the whole of the front of the chest.
3. *Abdominal head:* It arises from the lower left region of the abdomen.

The pectoralis major muscle, after taking its origin from the aforementioned places, inserts itself into the anterosuperior aspect of the humerus (the upper front portion of the upper bone of the arm). Due to its multiple origins and insertion, the pectoralis major muscle is an important player in multiple movements and a wide range of actions:

- It helps in adduction and flexion as well as internal rotation of the humerus when the thorax is fixed. It brings the arms to the front, as in a bench press maneuver.
- It serves as a climbing muscle and helps in elevation of the thorax when the humerus is fixed.
- It also serves as an accessory muscle for respiration.

Causes and Risk Factors

The injury most commonly occurs when the pectoralis muscle is put under tremendous tension or supplementary forceful tension. It occurs most often in weight lifting (more than 50% of cases), especially with the bench press maneuver. Apart from this, the strain may occur in athletes participating in racquet games, swimming, water skiing, and rowing. Traumatic injuries such as those suffered in wrestling, American football, and rugby may also lead to a pectoral strain.

The following factors predispose to the condition:

- A weak and tight pectoralis major muscle, resulting from lack of proper conditioning in the prematch period
- Fatigue
- Overexertion
- Lack of proper warming up prior to exercise (cold weather requires extra warming up)
- Steroid use, which is known to weaken the tendons and may be a contributory factor

Types of Pectoral Rupture

There are three types of pectoralis rupture:

Type 1: Rupture at the humeral insertion (tendon ruptured from the bone)

Type 2: Rupture at the musculotendinous junction (rupture in between the tendon and the muscle)

Type 3: Rupture of the muscle belly (rupture in the muscle itself)

Usually, Type 1 ruptures are full tears, while Type 2 and Type 3 are typically partial ruptures.

Signs and Symptoms

The following effects are usually encountered in a pectoralis strain:

- Pain is one of the dominant symptoms of this condition. It may be accompanied by a tearing or "pop" sound. It can take the following forms:
  - A sudden sharp pain at the front of the arm or shoulder
  - Pain in the chest
  - Pain felt when the arm is brought inward toward the chest against resistance
  - Pain felt when trying to rotate the arm inward
- Bruising may be seen in the chest and arm.
- There may be weakness when bringing the arms to the front of the body.
- A pocket (dimpling) may be formed above the armpit, indicating a tear.
- Decreased range of motion may be observed at the humerus (upper arm) as a result of the rupture.

Grading of Severity

The condition can be graded according to the severity of the pain and associated symptoms:

Grade I: This involves the tearing of a few muscle or tendon fibers. There is minimal loss of strength. It causes minor discomfort but doesn't hinder activity. Recovery occurs in a matter of days.

Grade II: This involves a greater number of torn fibers and loss of strength to a greater extent. It causes greater discomfort and can begin to limit activity. Swelling and bruising may also be seen. Recovery may take 2 to 6 weeks.

Grade III: This type of strain is very rare, painful, and incapacitating. It can have long-term implications on strength, range of motion, and sports performance. In the majority of such cases, the muscles fail to regain their original strength. Significant swelling and bruising are often present. Recovery may take 3 months or longer.

Diagnosis

The diagnosis is often apparent by history alone, but sometimes a clinical examination can show some peculiar features:

History

The patient may give a history of injury or complain of pain, weakness, or decreased movement. He or she will often report hearing a "pop" or feeling a tearing sensation at the onset of the pain.

Clinical Examination

- Maximal peculiar muscular contraction will be observed when the arm is abducted and extended.
- Tenderness, limited mobility, swelling, ecchymosis (bruising), and weakness will be manifested in the front of the shoulder or chest.
- Loss of axillary fold is also probable. The best position to observe this is when the arm is abducted to 90°; however, this can only be done after the swelling has subsided.
- The location of ecchymosis (bruising) may signify the location of the injury. If ecchymosis is observed in the front of the chest, then it is most probably a muscle belly tear. If, however, the bruising is in the axilla or arm region, then it most probably signifies a tendon rupture at its site of insertion.

Imaging

- An X-ray is taken to rule out a fracture of the upper part of the humerus.
- Ultrasound may be performed to determine the location of the tear. A tear is indicated by muscle thinning in comparison with the normal side and uneven echo generation.
- Magnetic resonance imaging (MRI) can show the exact location of the injury and evaluate partial tears. It also helps with grading the severity of the injury.

Treatment

First Aid

Athletes should be trained to recognize the symptoms and perform RICE (*r*est, *i*ce, *c*ompression, and *e*levation) immediately. They should be careful not to strain the muscle further at any cost; rest is essential. A sling may be used for immobilization and elevation. Any activity that causes chest wall pain should be limited.

Professional Treatment

Treatment depends on the severity of the injury. One or all of the following may be considered.

Initial Treatment

Rest: This is the first and foremost principle to recover from any muscle strain. Exercise should be stopped to permit the body to repair itself.

Local cold pack/ice: Ice or cold packs on the injury during the first 2 days are often very helpful in easing the pain and swelling. Ice should be applied for 15 to 20 minutes four times a day, wrapped in a towel to avoid direct contact. Ice application should be started immediately after injury and can be extended for several days if necessary; the process can be repeated after any activity involving the affected area.

Oral nonsteroidal anti-inflammatory drugs (NSAIDs): Examples are painkillers such as ibuprofen or aspirin tablets.

Subsequent Treatment

Stretching: Similar to recovering from any other muscle strain, once the pain has subsided and range of motion has returned, stretching exercises should be incorporated into the routine. Gentle stretching is advisable, although care must be taken not to overdo it as excessive stretching may be counterproductive. A gentle pulling sensation is the aim, but the stretch should not be painful. Stretching should be done in the recovery period and can be done several times a day. Cross-training activities that do not stress the pectoralis muscles, such as jogging, should also be incorporated.

Local application of heat: While cold is helpful after activity, heat is of benefit before any activity is undertaken (e.g., stretching), to soften the area and reduce any chance of further aggravation of the injury. However, use of heat should be started in the recovery period, not in the period immediately following the injury.

Physiotherapy: Ultrasound treatment, infrared treatment, specific exercises, and massage by trained physiotherapists under the supervision and guidance of sports injury specialists or rehabilitation specialists are often of great value in speeding up the recovery period and preventing complications.

Diet: Supplementary protein is advocated for repair of the torn muscle.

Strengthening exercises: The following are a few of the strengthening exercises that can be incorporated:

- ○ Active isolated pectoralis stretch: The patient stands in a comfortable position, with the arms raised and palms facing up. Then, the back muscles are contracted to bring the arms to the sides with the palms still facing up. Stretching to the point of pain should be avoided. Repeat 10 times.
- ○ Quadruped stance: The patient supports himself or herself on the hands and knees. Once the patient is comfortable, he or she extends into the push-up position and holds the body in this plank position. The duration of this exercise should be gradually increased, but the patient should not hold until the point of pain.
- ○ Resisted internal rotation: The patient starts with the arm at the side, holding an elastic tube that is tied to a stable surface. He or she then gently rotates the hand toward the belly button and then releases it. This action should be repeated 10 to 15 times. The patient should use a band that offers a moderate amount of resistance but no pain.

Surgery: This is frequently recommended for complete tears of the pectoralis muscle tendon. Patients with partial tears, elderly patients, and patients with a sedentary lifestyle can avoid surgical treatment. Surgical repair of the torn tendons gives patients a good chance of returning to high-level sports and activities. Preferably, the surgical repair is done early following injury as it minimizes muscle atrophy and scar tissue. Early surgical repair shortens the time to functional recovery and lessens the occurrence of lesions. However, there are some studies that show that late repair improves strength and cosmesis (appearance of the chest).

Prevention

The most important factor in prevention of this injury is proper conditioning of athletes, especially those who participate in sports where a pectoral strain is more likely. To ensure pectoral strength, athletes must

- warm up properly before any exercise,
- allow more time for warm-up in cold weather,
- get help from a certified strength-and-conditioning coach to learn a proper lifting technique,

- take care not to increase exercise intensity, duration, or frequency by more than 10% per week, and
- continually work out, for the stronger the muscles, the less will be the likelihood of their rupture.

Weight lifters, in particular, should be advised on the proper bench press technique. They should limit the distance that the bar is lowered and narrow the grip of the hands on the bar. Lowering the bar down to the chest or widening the grip on the bar increases stress on the pectoralis major muscle and increases the chance of pectoralis injury.

High-performance athletes who keep the cardinal principles of prevention in mind and are disciplined in their approach toward the game can usually avoid this kind of needless injury and have a rewarding career.

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Pediatric Obesity, Sports, and Exercise

Over the past few decades, two problems have emerged regarding physical activity in youth. First and foremost, in the United States and many other industrialized countries, far too many youth are inactive, resulting in too little energy expenditure and contributing to the soaring rates of childhood obesity. On the flip side, some youth are engaging in extreme amounts of organized sports activity. Both scenarios result in musculoskeletal conditions that are seen daily in youth in the practice of sports medicine. Of note, the evolution of youth sports may be resulting in the exclusion of those children who could most gain from the health benefits of sports participation.

Role of Sports in Addressing the Physical Activity Needs of Children and Adolescents

It is recommended that children and adolescents participate in at least 60 minutes of moderate physical activity on most days of the week. Discussions about physical activity have focused on the need to increase the percentage of children meeting this recommendation. This is for a good reason. Epidemiological studies have found that physical activity is inversely associated with overweight status in childhood. Overweight status is clinically assessed by calculating the body mass index, or BMI, determined by weight (in kilograms) divided by height (in meters) squared. In the United States, the 2003–2006 National Health and Nutrition Survey (NHANES) found that approximately 30% of U.S. youth, from ages 2 to 19 years, are either overweight or obese as determined by a BMI that is greater than or equal to the 85th percentile as compared with the 2000 Centers for Disease Control standards. Childhood obesity has clearly become a global problem. While the rates are higher in the more industrialized countries, worldwide national surveys show that childhood obesity rates are rising in most countries. Childhood obesity is associated with poor physical and psychological health.

Participation in team or individual sports is a wonderful means for children and adolescents to be physically active. In addition to the physical health benefits of exercise, such as cardiovascular and bone health, youth sports participation is associated with a variety of psychological benefits. Many of the psychological and emotional morbidities seen in childhood obesity, such as depression and anxiety, may be decreased with participation in sports. Sports can offer youth a venue for socialization, the ability to develop moral reasoning skills in a safe environment, and the opportunity to experience either the joy of winning or the satisfaction of knowing that they have tried their best in a competition. In summary, youth sports offer a means to address both the physical activity needs of children and the psychological difficulties that arise when those needs are not met. Given the problems of obesity and inactivity among adults, it is important to note that participation in sports during childhood and adolescence is associated with a high level of physical activity in adulthood. A positive experience with sports in childhood and adolescence can be the foundation for a future reaping the health benefits of physical activity.

Youth Sports Today

Clinical experience suggests that there has been a dramatic rise in the amount of time spent by children in organized sports with formal teams, coaches, and multiple weekly practices and games. It appears that children are being channeled into single-sport specialization, often before the age of 10. In Minnesota, children participating in ice hockey are being selected for teams based on ability by age 6. Practice times in certain sports are increased steadily throughout childhood. By the age of 10, many children play on organized teams four or more times per week and often year-round. Two potential consequences of this are psychological burnout and overuse injuries.

Many youth sports clubs encourage year-round participation. Given the number of hours involved in participating in any one sport, these children, and their families, are faced with a choice: either participate in multiple sports and further increase the number of hours of sports participation or become a single-sport athlete at a very young age. It has been estimated that approximately 70% of children participating in any one sport will stop playing in their early teenage years. If a child who participates in only one sport stops playing, he or she may become a no-sport athlete, a phenomenon that likely contributes to the sharp decline in physical activity during adolescence.

Our Current System for Youth Sports Excludes Those at High Risk for Obesity

The development of our current organized sports system may not be including the demographic groups that could gain the most from the health benefits of sports participation. There seem to be fewer opportunities for play in recreational leagues for children not selected to the "traveling squads." Thus, there is less chance of sports participation for any child but those on the elite teams. The selection process for these teams tends to exclude certain groups of children. For example, pediatric obesity disproportionately affects less affluent children and adolescents. Yet organized youth club sports often require high fees for participation and significant investment by families for equipment and travel. There are decreasing opportunities for participation in school sports, and even when schools include sports, financial contributions from families are increasingly required to offset declining public investment. These financial constraints pose a barrier to sports participation by youth from less affluent families, many of whom already have too little physical activity.

There is increasing recognition that children who are not gifted with physical coordination skills participate less in physical activity and are more likely to be obese. The term *developmental coordination disorder* (DCD) has been used to describe otherwise healthy children with impairment in motor skills considered to be appropriate for their age, given normal intellectual ability and the absence of other neurologic disorders. DCD is believed to affect between 5% and 10% of youth, with higher rates in boys than in girls. There is mounting research documenting that these children participate in fewer organized and free-play physical activities, and in boys, there is an association with obesity and loneliness. Importantly, this association of poor coordination and loneliness seems to be weakened when these children participate in sports (likely due to the social aspect of sports).

Adolescents who were born with "extreme prematurity" and low birth weight but without major impairments show significantly lower rates of sports participation than do controls. Extremely low–birth weight babies are at high risk for obesity and obesity-related cardiovascular abnormalities. While their lack of sports participation is likely due to problems with coordination, which makes them prefer to avoid sports, it serves to highlight again that those who need sports the most are participating at lower rates than those who need them the least.

In summary, sports participation seems to be lowest among those at greatest risk for childhood obesity—for example, those with lesser economic means, those with coordination difficulties, and those who were born prematurely. Youth sports today aim to increase the average number of hours children spend in physical activity but may not be increasing the average number of children reaching the recommended goal for physical activity.

Pediatric Sports Medicine: A Problem of Overuse and Underuse

Youth Sports Participation and Musculoskeletal Injuries

Sports are generally safe, and the health benefits outweigh the risks. However, sports can cause either acute injuries or, with excessive training, overuse injuries. Sports are a leading cause of injury and hospital emergency room visits among adolescents. A review estimated 2.6 million emergency room visits in the United States for sports-related injuries by those between the ages of 5 and 24 years. Most of these visits are by boys between the ages of 5 and 14. Most of these are for acute injuries, such as sprains (of ligaments), strains (of muscles or tendons), contusions, and fractures. Fractures account for 20% to 30% of sports-related visits to the emergency room. There is a male predominance of 2:1, with the distal radius and ulna accounting for the most common fracture site. Anterior cruciate ligament (ACL) injuries of the knee are believed by some to be the single largest problem in orthopedic sports medicine. The most common mechanism is a noncontact deceleration injury. This mechanism is more common in female sports participants. In similar sports, consistently higher rates of ACL tears occur among female sports participants than among males. While many of those who suffer ACL tears return to sports, often after reconstructive surgery, an ACL injury itself is associated with a significant rehabilitation process and a high probability for future arthritis.

With the increased sports participation by those in organized sports, there has been a dramatic rise in musculoskeletal overuse injuries. Injuries may be attributed to overuse when there is no specific acute event and the athlete's participation is deemed excessive. Common overuse injuries include stress fractures and soft tissue injuries that are not the result of a contusion. Stress fractures in young athletes often occur in runners and often in the tibia. Especially problematic areas are the hip and the lower back (e.g., spondylolytic injuries). Additionally, excessive traction on growth plates can cause a variant of the typical stress fracture, as in the case of the proximal humerus in the throwing athlete (Little League shoulder). Among the classic soft tissue overuse injuries in youth are injuries to the apophyses, for example, at the junction of the patellar tendon with the tibial tubercle (Osgood-Schlatter syndrome) and the Achilles tendon with the calcaneus (Sever syndrome). Apophyseal injuries tend to cluster in the peripubescent years of accelerated skeletal growth.

In the treatment of youth overuse injuries, sports medicine providers must be skilled in dealing with not only the physical aspects of injury and healing but also the more subtle issues surrounding the motivations of youth athletes, their parents, and their coaches. Treatment often requires avoidance of repetitive activity for several weeks, or even months. This may seem especially problematic for athletes who are in year-round programs and who fear that any extended time away will lose them a spot on the team. It is important to recognize that adolescents often place extra importance on immediate issues (e.g., playing in the upcoming tournament) at the cost of long-term consequences (e.g., further damaging a fractured bone). When treating a minor, the sports medicine clinician must include the parents, and thus parental motivation must be evaluated. It is recommended to discuss the athletic goals for the patient/athlete with both the athlete and his or her parents. The sports medicine provider can often use the competitive nature of the athlete to increase adherence to treatment recommendations. For example, when treating the star high school freshman volleyball player with knee pain attributable to Osgood-Schlatter apophysitis a few months away from jumping, a focus on biomechanical stability training may result in a senior volleyball player who is a stronger candidate for a college scholarship.

Pediatric Obesity and Musculoskeletal Injuries

Lack of physical activity is a major cause of the childhood obesity epidemic. This underuse of the musculoskeletal system with subsequent increase in body weight may result in musculoskeletal conditions requiring the care of a sports medicine specialist. Childhood obesity is associated with a variety of biomechanical changes, especially in the lower extremities. Obesity in children is associated with changes in gait. These biomechanical changes coupled with the extra weight result in excessive forces on the lower extremity joints. Perhaps due to changes in balance, childhood obesity may be a risk factor for injuries, and studies have noted an increased risk of upper extremity fractures in overweight children. While obese children have denser bones than their nonobese counterparts, the increased bone strength is not sufficient to compensate for their increased weight. A recent study noted that children who are obese are more likely to suffer long-term morbidity after acute ankle sprains than are children with normal BMI.

For years, childhood obesity has been associated with certain rare conditions such as Blount disease (an angular deformity of the tibia causing a bowlegged appearance) and slipped capital femoral epiphysis. Recently, there is increased appreciation that obese children suffer from musculoskeletal pain due to more subtle issues. Although these pains are less acute, they may have a large impact on quality of life and the ability to perform needed physical activity. Recent studies have shown that obese children report more musculoskeletal pain than nonobese children and that among obese children, those with more body weight have a greater likelihood of experiencing pain.

As outlined in Figure 1, similar to their peers who are participating in excessive amounts of physical activity, obese and generally more sedentary children are also at high risk for musculoskeletal pains, which may lead them to the sports medicine clinician's office. Both ends of the physical activity spectrum could be improved by a balanced youth sports system. It is recommended that obese children increase their physical activity to expend energy and lose weight. However, recommendations to have overweight and obese children exercise need to be given with the understanding that once excessive weight has developed, there may be musculoskeletal issues directly limiting the ability to increase physical activity. Clinicians need to individualize their recommendations and consider exercises such as weight training, pool exercises, and bicycling, all of which may lessen the effect of body weight and the occurrence of subsequent joint pains when compared with traditional walking and running.

Certain Sports Encourage Excessive Body Weight

Sports participation is, in general, recommended for the prevention of childhood obesity. However, certain sports, where increased size confers an advantage, may be directly contributing to the rise in obesity. Increased body size is a potential benefit in many sports, most notably American football. The body weight of football players has been increasing over the past few decades. A study of a Division I football program found that from 2003 to 2005, the average BMI for the incoming freshman football players was 30 (i.e., at the cutoff line for obesity). The mean BMI of the linemen was clearly in the obese range (34 and 35 for the defensive and offensive linemen, respectively). The players in the other positions had mean BMI in the overweight range (25–30). These players are likely to gain weight during subsequent years of participation. A survey of former professional football players (mean age at the time of the survey, 54 years) conducted from 2004 to 2006 found that among the former linemen 85% were obese and 60% met the criteria for the cardiovascular risk factors known as "the metabolic syndrome." Among the nonlinemen, 50% were obese, and 30% had the metabolic syndrome.

The problem of sports increasingly selecting larger children may not be limited to football. Physical maturation seems to be the primary selection factor for many youth sports, and this criterion will only become more pronounced as children are funneled into sports at an increasingly younger age. Unlike adults, in children there is a positive association between BMI and height. Children with increased BMI are often more skeletally mature. However, early skeletal maturation is also associated with future obesity. If increased BMI and height are advantageous in a sport, then youth sports that select children who are bigger and taller (especially in prepuberty) may be encouraging development that leads to future obesity. While the energy expenditure is beneficial for a healthy body weight, encouraging increased size is not.

Conclusion

Many of today's youth fall at the two ends of the physical activity spectrum. Both ends of the spectrum are associated with musculoskeletal problems that are seen in the practice of pediatric sports medicine. From a public health perspective, the major

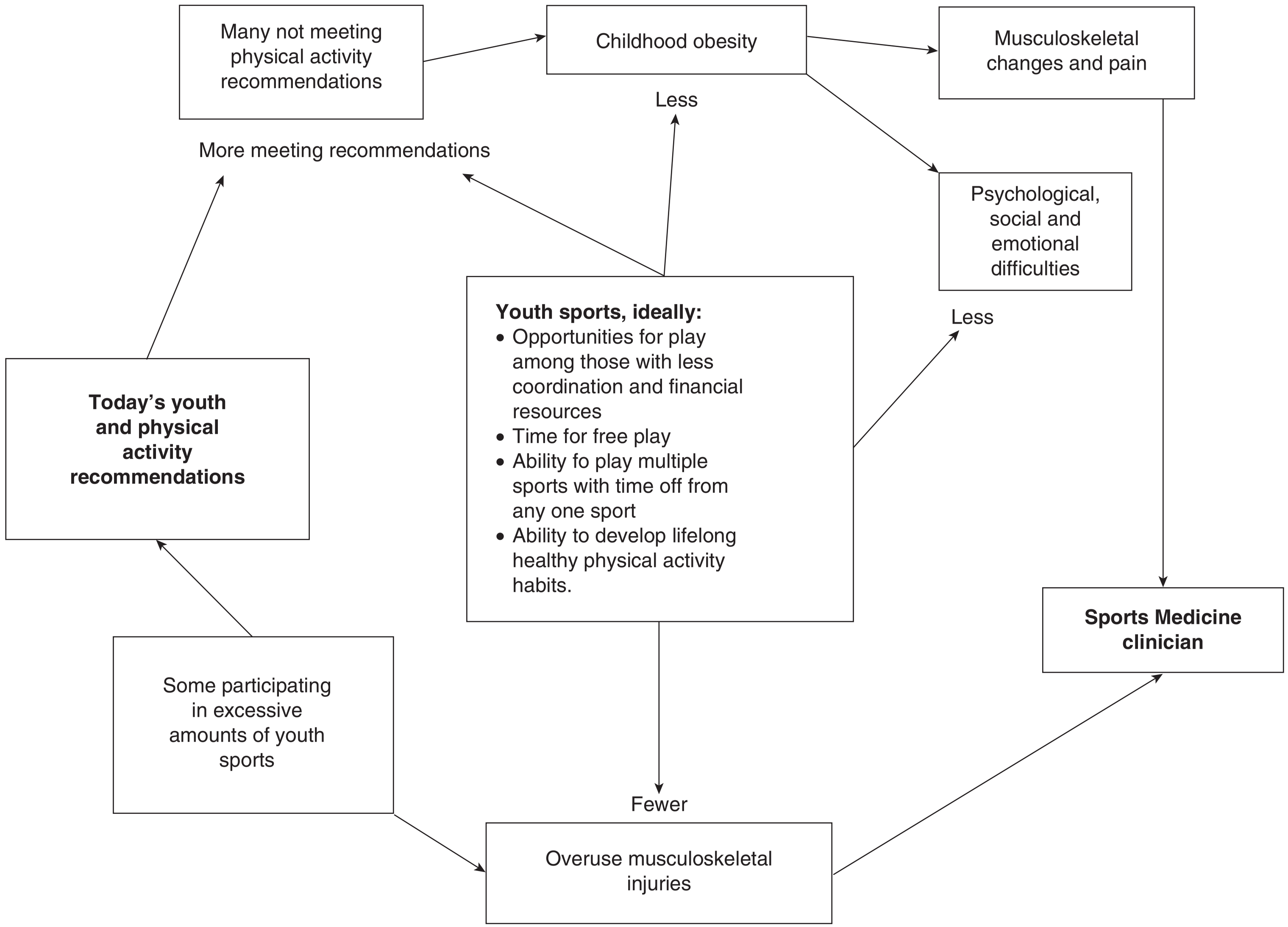

Figure 1 Interrelationships of Pediatric Obesity, Sports, and the Sports Medicine Clinician
Source: Steven D. Stovitz.

problem is that too few youth are achieving the recommended amount of physical activity. Lack of physical activity places them at risk for obesity, and obesity causes musculoskeletal changes that may result in pain and poor function. One answer to the goal of increasing physical activity in youth is youth sports. Youth sports offer a means to increase physical activity in the present and provide a foundation for a physically active future. However, recent trends in the evolution of youth sports may be hindering the attainment of these goals for those youth who need physical activity the most. Furthermore, for those in youth sports, the demands of increased physical activity may result in psychological burnout and overuse musculoskeletal injuries. It is important for the sports medicine provider to be able to individualize treatment for youth with musculoskeletal pain due to either excessive body fat or excessive body training.

Summary

- Pediatric obesity, which is partly the result of insufficient energy expenditure, is a major health problem in many parts of the world.
- Physical activity in general, and sports in particular, is recommended as a means to prevent and treat pediatric obesity
- Sports participation may be difficult for the child with extreme overweight due to changes in the musculoskeletal system and pain.
- The recent trends in childhood sports may be inadvertently excluding children at the greatest risk for obesity.
- Sports such as American football may be selecting for traits that entail increased rates of obesity.
- Sports medicine providers can be at the forefront of encouraging a healthy and physically active lifestyle for children. Some suggestions are as follows:
  - Encourage lifestyle means of increasing physical activity, such as using nonmotorized means of transportation and decreasing television watching and other "screen time," for example, surfing on the Internet.
  - Advocate for increasing the opportunities for sports participation for all children, regardless of athletic ability.
  - Counsel coaches and parents on the risk of overuse musculoskeletal injuries from excessive hours of organized sports participation, especially in a single sport with repetitive actions.
  - Recognize that obesity in children may cause musculoskeletal changes and pain that may limit their ability to perform certain activities. Individualized activity options may be indicated.

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Note: The author would like to thank Toben Nelson, PhD, and John Sirard, PhD, for their helpful comments on this entry. Both are colleagues in the University of Minnesota's multidisciplinary study group Sports, Society and Health.

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Pelvic Avulsion Fractures

Pelvic avulsion fractures are almost exclusively seen in the adolescent athletic population. The main reason for this is the relatively weak apophysis of the hip at this stage of development. An apophysis is a growing part of the bone where a large muscle group attaches. The apophysis is a secondary center of ossification that contributes to the shape or contour of the bone but not to the length of the bone. This is in contrast to the physeal growth plate, which adds to the length of the bone. This relative weak link in the chain predisposes the apophysis to avulsion fracture when coupled with a violent contraction of one of the large hip muscles that attach there.

The apophyses of the hip appear and eventually fuse at different ages and in some cases may not fuse until the third decade of life. Hence, apophyseal avulsion fractures can occur in an athlete as late as 30 years of age. The following table gives the approximate ages of appearance and fusion of the apophyses of the hip:

Apophysis	*Age of Appearance (Years)*	*Age of Fusion (Years)*
Iliac crest	13–15	15–17
Anterior superior iliac spine (ASIS)	13–15	21–25
Anterior inferior iliac spine (AIIS)	13–15	16–18
Greater trochanter (GT)	2–5	16–18
Lesser trochanter (LT)	8–12	16–18
Ischial tuberosity (IT)	16–18	19–25

The large muscle groups that attach to the pelvic apophyses are the transverus abdominus and internal and external oblique muscles, and the gluteus medius and tensor fasca lata muscles attach to the iliac crest apophysis. The anterior superior iliac spine (ASIS) apophysis is the site of origin of the sartorius muscle. The anterior inferior iliac spine (AIIS) apophysis is the site of origin of the straight head of the rectus femoris muscle. The greater trochanter (GT) apophysis is the insertion site of the gluteus medius and minimus and external rotators of the hip. The lesser trochanter (LT) apophysis is the insertion site of the iliopsoas muscle. The ischial tuberosity (IT) apophysis is the site of origin of the hamstring muscles.

Pelvic avulsion fractures are generally considered to be an uncommon injury, but their rates have been increasing over the years. Studies have reported rates of avulsion fractures between 13.4% and 40% of all pelvic and hip fractures in the adolescent population. A study by Rossi looked at 20 adolescent patients with acute pelvic avulsion fractures and found that the most common sites of injury were the ishial tuberosity, lesser trochanter, ASIS, and AIIS. The most common sports involved were gymnastics and soccer. The majority of the athletes in the study were males, but the injury is being seen more frequently in females as their rates of participation in sports are increasing. These injuries occur most commonly during Tanner Stage III, when the rate of growth is the fastest.

The most common mechanism of injury in an acute pelvic avulsion fracture is a sudden, forceful, unbalanced contraction of one of the major muscle groups that attach there. The athlete may feel a "pop" or a "snap" during activity, followed by sudden, severe pain. The athlete will usually be unable to ambulate without pain and will be forced to cease activity. Physical exam may show swelling and bony tenderness over the involved bony prominence. X-rays are needed to confirm the diagnosis. Comparison views of the opposite side are very helpful to rule in the fracture, since usually the opposite side will show the same growth stage.

Most avulsion fractures will respond adequately to a conservative treatment plan. In almost all cases, the athlete will need to walk with crutches to give rest to the joint. J. N. Metzmaker and A. M. Pappas modified a five-stage program for conservative rehabilitation of an acute apophyseal avulsion fracture. Stage 1 involves rest in a position of comfort (crutches), ice application, and anti-inflammatory medication for pain relief. Stage 2 involves a gradual increase in passive range of motion in the affected joint. Stage 3 begins when full active range of motion is achieved and involves a comprehensive resistance training program. Stage 4 begins when the athlete has gained 30% of his or her strength compared with the uninvolved side and sees the athlete incorporating the involved muscle group in rehabilitation. Stage 5 involves allowing return to play when the athlete regains full strength and pain-free integration of the involved muscle group.

Surgical intervention is considered when the avulsed fragment is displaced greater than 2 centimeters (cm), the fracture heals with symptomatic bony overgrowth, or it heals with chronic fibrous union. Surgical treatments include excision of the bony fragment or open reduction and internal fixation if the fragment is large enough to accept the hardware.

Ischial Tuberosity Avulsion Fracture

The IT is the site of origin of the hamstring muscles. The hamstring muscles function to extend the hip and flex the knee. Hence, avulsion fractures of the IT are usually caused by a sudden, forceful contraction of the hamstring muscle with the knee in extension and the hip in flexion, as occurs when an athlete jumps a hurdle or performs the splits. The IT apophysis fuses late, between 19 and 25 years of age, so the diagnosis of IT apophyseal avulsion fracture should be entertained and the appropriate X-rays ordered in the athlete in his or her third decade. This is thought to be the most common site of pelvic avulsion fracture (Figure 1).

Acutely, the athlete may find it impossible to sit due to the location of the fracture fragment and may have difficulty walking. A palpable gap may be noted, and the athlete may have pain with passive hip flexion. X-rays may show the fracture as large and crescent shaped.

An IT avulsion with less than 2 cm of displacement is usually successfully treated conservatively, including walking with crutches, rest, and slow return to activity. The IT avulsion fracture commonly heals with exuberant bony exostosis, which may lead to chronic buttock pain, difficulty sitting, and, in rare cases, sciatic nerve irritation. The exuberant bony changes can be confused with bony tumor. Treatment for chronic symptoms or a fracture fragment with greater than 2 cm displacement consists of surgical excision or open reduction and internal rotation.

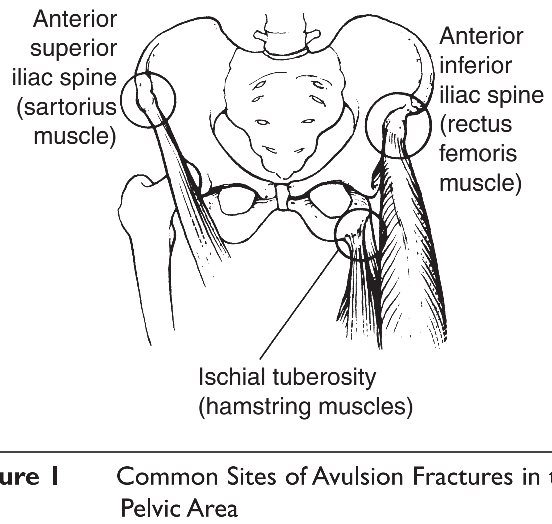

Figure 1 Common Sites of Avulsion Fractures in the Pelvic Area

Anterior Superior Iliac Spine Avulsion Fracture

The ASIS apophysis is the site of origin of the sartorius muscle, as well as several fibers of the tensor fascia lata. The sartorius muscle functions to flex the hip and is commonly avulsed during sprinting, hurdling, or running. Avulsion fracture of the ASIS is one of the more common avulsion fractures. The ASIS apophysis fuses between 21 and 25 years of age and hence can be seen in older athletes than the AIIS avulsion fracture.

At the time of injury, the athlete will usually feel or hear a "pop" and have immediate disability. Pain may be elicited by passive hip extension and with contraction of the hip flexors. In up to 90% of fractures, the avulsed fragment is palpable. As with all avulsion fractures, X-rays can confirm the diagnosis. ASIS fractures can be confused with AIIS fractures due to the inferior displacement of the ASIS fragment.

Most ASIS avulsion fractures can be treated successfully with a conservative treatment plan, including rest, walking with crutches, ice application, and analgesia. Complete recovery may take up to 10 weeks. Some authors recommend surgical treatment to allow a quicker return to sports (3–4 weeks), but generally, surgery is reserved for severe displacement, nonunion, or a rotated fragment.

Anterior Inferior Iliac Spine Avulsion Fracture

The AIIS is the site of origin of the straight head of the rectus femoris muscle, which is one of the muscles involved in hip flexion. A common mechanism of injury for the AIIS avulsion fracture is hip hyperextension and knee flexion, such as when a soccer player kicks a ball but meets the resistance of another player's foot. The injury is also seen in sprinters and hurdlers. The AIIS fracture is less commonly seen than the ASIS. It is sometimes referred to as "sprinter's fracture."

The athlete will usually complain of acute pain and be unable to bear weight. The pain may be more severe than in an ASIS fracture. The pain can be reproduced by passive extension of the hip or active flexion of the hip. The fracture fragment rarely displaces a great deal, due to the effect of the conjoined tendon. X-rays are used to confirm the diagnosis. The fracture fragment usually is crescent shaped or triangular. The injury can be confused with an os acetabuli, which is a normal finding and can be ruled out by comparison views of the opposite hip. The os acetabuli is usually bilateral, while the fracture should only be on the side of the injury.

The management of AIIS avulsion fracture is generally nonsurgical, including walking with crutches, rest, and slow return to activities. The injury may heal slowly, usually within 6 to 8 weeks. Rarely does the fracture heal with bony exostosis, but there is a report of two cases of exostosis, which required surgical excision.

Lesser Trochanter Avulsion Fracture

The LT of the femur is one of the attachment sites of the iliopsoas muscle. The iliopsoas is one of the main hip flexors, and hence, the injury is commonly seen in hurdlers, sprinters, and kickers. An LT avulsion fracture is a rare injury.

The athlete will present with acute pain and may be unable to walk. On exam, the athlete will be unable to actively flex the hip while seated, which is known as a positive Ludolph sign. The athlete will try to hold the hip in slight adduction and internal rotation to minimize the pain. X-rays can confirm the diagnosis but may need to be taken in slight external rotation to better visualize the avulsed LT fragment.

The fracture usually responds to conservative therapy consisting of a period of rest, limited activity, and protected weight bearing. The degree of displacement generally has no bearing on the prognosis, nor does it correlate with the severity or duration of the symptoms. The injury may take 10 to 12 weeks to heal completely.

Greater Trochanter Avulsion Fracture

The GT of the femur is the attachment site of multiple muscles, including the gluteus medius and minimus as well as the hip external rotators (obturator and gemelli). GT avulsion fractures are very rare but usually are caused by forceful muscle contraction of the hip abductors, such as when an athlete quickly changes direction.

As in most pelvic avulsion fractures, the athlete will present with acute onset of pain. The leg will be held in slight flexion and abduction. The patient may walk with a Trendelenburg gait, in which the involved hip doesn't elevate when walking. X-rays can confirm the diagnosis. Treatment is generally nonsurgical if the fragment is displaced less than 1 cm. Some surgeons recommend open reduction and internal fixation if the fragment is displaced more than 1 cm.

Iliac Crest Avulsion Fracture

The iliac crest is the insertion point of multiple muscle groups including the transversus abdominis muscle and the internal and external oblique muscles. An iliac crest avulsion fracture is a very rare injury and is usually caused by violent contraction of the transversus abdominis muscle, but it can also be caused by direct trauma. The mechanism of injury is usually a quick change of direction.

The management is nonsurgical, with non–weight bearing and progressive rehabilitation over 3 to 4 weeks. If the fragment is displaced more than 3 cm, surgical intervention may be considered.

Adductor Avulsion Fracture of the Symphysis Pubis

Though there is no true apophysis located at the symphysis pubis, this avulsion fracture deserves to be included in a discussion of pelvic avulsion fractures. The adductor longus, brevis, and gracilis muscles originate at this point, and an avulsion fracture may occur if there is a violent contraction of one of the adductor muscles. X-rays will show an undulated irregularity of the pubic symphysis. The treatment is conservative, with rest followed by slow return to activity.

Acetabular Rim Avulsion Fracture

A very rare example of avulsion fracture about the pelvis is an acetabular rim avulsion fracture. One case has been reported in the literature, in which the reflected head of the rectus femoris avulses a fragment from the acetabulum. The treatment is nonsurgical.

David M. Peck

See also Apophysitis; Hamstring Strain; Hip, Pelvis, and Groin Injuries; Hip Flexor Strain

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Pelvic Bursitis

Pelvic bursitis is inflammation of the bursae that lie around or within the hip/pelvis. There are three main types of pelvic bursitis: (1) greater trochanteric, (2) ischial, and (3) iliopectineal (sometimes called iliopsoas). Greater trochanteric bursitis is discussed in detail in its own entry. This entry focuses on iliopectineal and ischial bursitis, which are both relatively common causes of hip, pelvic, or groin pain.

Anatomy

Bursae are small fluid-filled sacs that are usually found around joints or bony prominences. Their purpose is to create lubrication between two uneven surfaces and provide frictionless movement, as well as serving as a pad or cushion. The pelvis is the bony structure located at the bottom of the spine. It has three components: the ilium, ischium, and pubis. The *ilium* is the large bone one feels at the outside of the waist, the *ischium* is the bone one feels when sitting on the buttocks, and the *pubis* bone, also called the pubic bone, is in the front just above the genital area (see Figure 1).

The two ischial bursa rest under the ischial bone (specifically, the ischial tuberosity) on each side of the pelvis near the attachment of the hamstring muscle. The iliopectineal bursa lies in the front of the hip and deep in the groin and results from the iliopsoas (hip flexor muscle) tendon sliding over another muscle (pectineus) and the bony prominence where the ilium and pubic bones join.

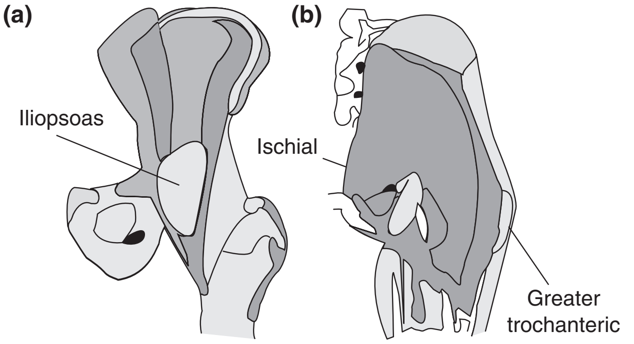

Figure 1 Bursae of the Hip and Pelvis: (a) Front and (b) Posterior View

Causes

Pelvic bursitis is caused by either overuse or direct trauma. Direct trauma such as a fall that causes the athlete to land on the buttock or a direct blow to the lower buttock or anterior hip may trigger an ischial or iliopectineal bursitis, respectively. These falls or blows will cause bleeding (hematoma) into the bursa, which then results in swelling. Usually, these hematomas are rapidly absorbed by the body, but not infrequently, they may result in scarring and thickening (calcifications), leading to a more chronic type of bursitis.

More commonly, chronic repetitive overuse is involved, which can occur from merely running or jumping. Injuries to the hamstring muscle or the hip flexor muscle can lead to ischial and iliopectineal bursitis, respectively. Other conditions that predispose athletes to this type of pelvic bursitis include postural abnormalities, which can be caused by scoliosis, degenerative spinal conditions, hip and knee arthritic conditions, leg length differences, flat feet, high-arched feet, overpronation of the feet, or even oversupination of the feet at heel strike. Improperly fitting shoes, worn-out shoes, running on uneven or hard (cement) surfaces, and sudden increases or changes in training are other causes of pelvic bursitis. At times, the bursitis develops spontaneously without any apparent cause, from infection or as a complication following hip surgery.

Symptoms

Ischial bursitis usually results from a direct blow or fall (such as in contact/collision sports), and athletes complain of pain at the ischial tuberosity that may worsen with sitting. Swelling and bruising may also be present. Pain mimicking ischial bursitis may be caused by hamstring syndrome. This syndrome also has pain around the tuberosity that gets worse with sitting, but athletes may complain of pain radiating down the back of the leg due to sciatic nerve compression within the hamstring muscle. Therefore, it is important to focus on the exact location and symptoms of this injury.

Iliopectineal bursitis is usually due to overuse and results in pain in the front of the hip that may radiate into the proximal thigh. Pain is usually worse with sports, especially stretching of the hip flexor muscle by hip extension, and may be associated with a limp. Athletes may also complain of a snapping sensation in the front of the hip due to the hip flexor tendon snapping over the bony prominence. The pain may also cause the athlete to keep the hip in a flexed and externally rotated position, such as sitting with the affected leg's foot on the opposite knee (figure-four position).

Diagnosis

Ischial and iliopectineal bursitis are both typically diagnosed by history and examination. On examination, ischial bursitis will exhibit tenderness to touch/pressure around the ischial tuberosity. Occasionally, bruising and swelling will be present. Pain is usually worse with passive stretch of the hamstring (hip flexion [forward bending] with knee extension [straightening]) or active contraction of the hamstring (hip extension [backward-bending] with knee flexion [bending]).

Iliopectineal bursitis will exhibit pain to deep touch/pressure on the front of the hip/groin, as well as pain with active hip flexion (especially while lying flat on the back and lifting the leg up about 15°) and passive hip extension. One may feel a snap in the front of the hip as the hip is actively flexed. Limping may be present, and athletes usually prefer the hip to be in the figure-four position as mentioned above.

One should also look for structural abnormalities on examination, including, but not limited to, scoliosis, leg length difference, and flat feet.

X-ray films of the hip or lower spine can be obtained to ensure that there are no bony abnormalities, such as spurs, calcifications, or arthritis, that could be contributing to the problem. Occasionally, ultrasound, magnetic resonance imaging (MRI), or a bone scan may be done if the diagnosis is unclear or if the problem does not resolve with treatment. These tests will help rule out tumor, infection, or subtle fracture of the bone.

Treatment

General treatment principles apply for both types of bursitis, including a combination of rest; heat and/or cold application; stretching and strengthening exercises; activity and shoe modification; pain medication such as acetaminophen or ibuprofen; and osteopathic manipulation along with correction of any anatomical or biomechanical asymmetry (by orthotics/heel lifts). Cross-training incorporating low-impact activity, such as biking, swimming, or using elliptical machines, can minimize the pain and allow for continued exercise. Special padding may need to be worn by those athletes involved in contact sports to minimize further irritation. Typically, resolution of symptoms occurs within 2 to 6 weeks of treatment. More advanced treatments, such as physical therapy, cortisone injections, or surgery, may be required for persistent symptoms.

Ischial bursitis. Specific treatment for ischial bursitis includes rest; ice for direct trauma followed by heat application (heat alone for overuse); stretching of the hamstrings, hip flexors, adductors, and iliotibial band; and strengthening of the gluteus muscles, hamstrings, and lower abdominals. If the pain continues, the physician can drain the fluid from the swollen bursa and inject a corticosteroid into the area to help reduce the inflammation and pain. This can be done using the same technique described in the entry Trochanteric Bursitis with or without radiologic (ultrasound) guidance. Other treatments used in physical therapy can also be employed, such as phonophoresis, which uses ultrasonic sound waves to allow for deep penetration of topical medications, or iontophoresis, which uses an electrical current to allow corticosteroids to penetrate the skin and minimize the inflammation of the bursa. Ultrasound therapy and soft tissue massage may also be helpful. Surgical excision of the bursa with removal of ischial bone spurs is reserved for the rare, nonresponsive cases.

Iliopectineal bursitis. Treatment includes rest, ice for direct trauma followed by heat application (heat alone for overuse), and hip flexor/groin/hamstring/IT band stretching and strengthening of the buttock muscles (gluteus maximus and medius), hip flexor, and lower abdominals. Phonophoresis, iontophoresis, and ultrasound may also provide some relief. Corticosteroid injections have been successfully used but are probably best administered under radiologic guidance (ultrasound) in this area to prevent damage to the surrounding nerves and/or blood vessels. Athletes should be made aware of the risks of any injection prior to the procedure and should avoid strenuous activity for several days following a cortisone injection to decrease the chance of tendon rupture. Surgery, consisting of either release or lengthening of the hip flexor muscle near its attachment on the thighbone (lesser trochanter of the femur), has been performed successfully. Surgical intervention carries the increased risk of anesthesia along with the direct surgical risks and should be considered only after appropriate nonoperative interventions have been exhausted.

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See also Hamstring Strain; Hip, Pelvis, and Groin Injuries; Hip Flexor Strain; Hip Flexor Tendinitis; Trochanteric Bursitis

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Pelvic Fracture

Pelvic fractures in the athlete can range from simple avulsion injuries to pelvic ring disruptions. Avulsion fractures of the pelvis represent an injury unique to the adolescent and young adult athletic population as the result of an imbalance between the strong muscle attachments and the weaker apophysis. Fractures of the pelvic ring are often the result of high-energy injuries (cycling or skiing accidents) and may occur in isolation or in conjunction with multiple injuries, necessitating specialized treatment.

Anatomy

The bony pelvis can be thought of as a ring with the sacrum connecting the two halves of the pelvis, formed from the ilium, ischium, and pubis. There are five so-called secondary centers of ossification, also known as apophyses, around the pelvis that serve as attachment sites for muscle origins and insertions. These include the iliac crest, anterior superior iliac spine (ASIS), anterior inferior iliac spine (AIIS), ischial tuberosity, and pubic symphysis. The external abdominal obliques insert on the iliac crests and help with trunk rotation. From the ASIS, two muscles originate, the tensor fascia lata and the sartorius, the major actions of which are to flex the hip. The rectus femoris, which helps flex the hip and extend the knee, originates from the AIIS. The large group of hamstring muscles responsible for knee flexion and hip extension has a proximal attachment to the ischial tuberosity, and the hip adductors attach to the pubic symphysis.

Causes

Avulsion fractures of the apophysis are most commonly caused by participation in sports such as soccer, rugby, ice hockey, and gymnastics and activities that involve sprinting, including track, baseball, and football. These injuries are typically the result of indirect trauma caused by a sudden, strong, or unbalanced contraction of the muscle attached to the apophysis.

The three most common avulsion fractures are those that occur at the ischial tuberosity, ASIS, and AIIS. The ischial tuberosity is often fractured as the result of a forceful eccentric contracture of the hamstrings during sprinting or hurdling activities. Fractures of the ASIS commonly occur during running activities as a result of the forces generated by the sartorius muscle. Some authors have also reported that a twisting mechanism, such as swinging a baseball bat, can cause the tensor fascia lata muscle to avulse the ASIS. Injuries to the AIIS occur when the muscles of the anterior thigh are loaded in hip flexion and knee extension—such as during kicking or a forceful push-off in sprinting—and cause a large force across the weaker apophysis.

Symptoms

Avulsion fractures commonly present with a sudden onset of pain during physical activity and may be accompanied by a "pop." Walking may be difficult and uncomfortable immediately after the injury. Direct palpation over the fractured apophysis is painful, and stretching of the muscle group attached to the fractured apophyseal fragment will cause discomfort. Manual muscle testing of the affected muscle group will be painful, and the muscles will appear notably weaker.

Avulsion fractures of the ischial tuberosity present with pain in the back of the upper thigh and buttock region, and there is pain with sitting and standing and discomfort with stretching of the hamstring muscles. Avulsion fractures of the ASIS and AIIS present similarly with pain and a "pop" during activity. Palpation over the location of the apophysis is often painful, and there is pain and weakness with attempts at hip flexion or passive stretching of the hip in extension.

Sometimes these injuries are thought to be a "pulled muscle" or muscle strain, which can result in a delay in proper diagnosis.

Diagnosis

The diagnosis of an avulsion fracture is usually made from the history, physical examination, and X-ray. A plain anteroposterior radiograph of the pelvis can show the displaced apophyseal fragment and fracture, but occasionally, other oblique radiographic views such as Judet views are needed to properly see the fracture. Other imaging modalities including computed tomography (CT), magnetic resonance imaging (MRI), or ultrasound can be used to better define the location of the injury and the amount of displacement of the fractured fragment.

Treatment

Nonsurgical Treatment

Nonoperative management with a guided rehabilitation program is the mainstay of treatment for apophyseal injuries. J. N. Metzmaker and A. M. Pappas describe a five-phase rehabilitation protocol for the treatment of such injuries. The first stage includes rest, ice application, and pain medications, with the goal of resting and avoiding stretching of the injured muscle. Usually 1 week later, after the pain has resolved, range-of-motion exercises are started. Once motion is restored to near-normal levels, resistive exercises can be added to the program. Typically around 1 to 2 months after injury, stretching and strengthening with sport-specific goals are started, with the athlete returning to activity once full strength and range of motion have been achieved.

Surgery

For most avulsion fractures of the pelvis, operative intervention is indicated when nonoperative management has failed, in cases of painful nonunions, and occasionally if the fracture is initially displaced more than 2 centimeters. Some surgeons may treat ischial avulsion fractures primarily with operative fixation, due to development of painful calluses and scarring of the sciatic nerve with nonoperative treatment. Operative techniques may include excision of the bony fragment and reattaching the muscle unit with sutures or direct fixation of the bone using screws.

After Surgery

Postoperative management of avulsion fractures typically consists of a period of non– or partial weight bearing in the first 7 to 10 days after surgery, followed by progressive weight bearing with crutches for another 4 to 6 weeks. Injury- and sport-specific physical therapy is used during this time, with the goal of return to play by 3 to 4 months after surgery.

Young-Jo Kim and Brian Brighton

See also Avulsion Fractures; Hip, Pelvis, and Groin Injuries; Hip, Pelvis, and Groin Injuries, Surgery for; Sports Injuries, Acute

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Pelvic Stress Fracture

Stress fractures of the pelvis are a relatively uncommon injury in the general population, constituting less than 10% of reported stress fractures. Nevertheless, they represent a small but significant percentage of bone-related overuse injuries in selected populations, ranging from 10% to 20% of reported stress fractures in distance runners and soccer players to more than 22% in female military recruits. These injuries typically occur in either the pubic symphysis or the superior or inferior pubic ramus and can result in significant morbidity and loss of productivity.

Anatomy

The pelvis (from the Latin for *font*) is a bony ring at the base of the spine that forms the articulations between the axial and appendicular skeletons. It consists of two hip bones (os coxae), which are themselves composed of the ilium, the ischium, and the pubis. The ilium forms the widest and most superior portion of the pelvic girdle, while the ischium forms the inferior and posterior portion. The pubis is located anteriorly and creates the articulation between each hemipelvis. The pelvis articulates posteriorly with the axial skeleton at the sacroiliac joints.

There are significant differences in pelvic anatomy between males and females, which are mainly attributable to adaptations required for childbearing and the generally increased muscle mass of males. They include the following:

- A narrow, deep pelvis in males and a wide, shallow pelvis in females
- A heart-shaped pelvic aperture in males and a rounded or oval aperture in females
- A narrow pubic arch in males and a wide arch in females
- A large acetabulum in males, which is small and slightly anteriorly oriented in females
- A round obturator foramen in males, which is oval in females

Of these differences, perhaps the most significant in relationship to stress fractures of the pelvis is the angle of the pubic arch. The infrapubic angle tends to be around 60° in males and 90° in females. This results in a slightly flattened and elongated inferior ramus at the proximal attachments of the adductors and may explain some of the increase in pelvic stress fracture rates in females.

Causes

In general, stress fractures result from repeated stress across the bone, resulting in several small microfractures within the bony cortex. Over time, these microfractures can coalesce into a frank stress fracture. It is theorized that a disruption in usual bone homeostasis may be a primary factor in the development of stress fractures. As the exercise load increases, osteoclastic activity may outpace osteoblastic activity in the early period and result in bone injury. Additionally, intrinsic tensional forces across the bone may be a major contributor as they influence the process of bone remodeling. Factors that either accelerate the process of microfracture formation or alter the process of bony remodeling in the presence of new load requirements can contribute to the development of stress fracture.

Numerous risk factors for the development of stress fractures have been noted. Participation in activities that require a repetitive axial load to the skeleton, such as track-and-field events, marching, and long-distance running, has been shown to contribute to injury. During these types of activities, large muscle groups exert a high traction load across the bony insertion and initiate the cascade of stress-related events leading to a fracture. Poor preparticipation physical condition, especially when combined with a rapid increase in training activity, has been identified as a cause of pelvic stress fractures in military recruits. A history of a previous stress fracture also increases the risk of recurrence.

A disproportionate number of stress fractures in general, and pelvic stress fractures in particular, have been identified in females. The reasons for this are varied but may include hormonal or menstrual disturbances, nutritional deficiencies, and decreased bone density. The decreased angle of the pubic arch is posited as a significant contributor to stress fractures of the inferior pubic rami in females. The female athlete triad, a cluster of symptoms that includes amenorrhea, disordered eating patterns, and osteopenia (thinning of bone mass), perhaps due to the direct effect of decreased estrogen related to disrupted menstrual cycles, is another factor in the development of stress fractures in the female population. Stress fractures of the pelvis are rare in prepubescent individuals of either gender.

Diagnosis

As with any medical condition, a comprehensive history and physical examination are critical in diagnosing stress fractures of the pelvis. A thorough assessment of risk factors is important and should include questions related to the frequency and intensity of training, including recent changes in the training schedule; previous history of stress fractures; and other medical conditions that may predispose one to the development of stress fractures, such as nutritional, endocrine, or rheumatologic problems.

With stress fractures of the pubic rami, which are the more common of the two types, patients typically complain of chronic, diffuse pain in the groin, buttocks, or thigh that may be difficult to localize. Pain is exacerbated by activities such as running and jumping, but at least in the initial period, the pain may be of a relatively low level, and patients often continue to participate in sports activities. On physical examination, there is usually focal tenderness over the pubic ramus, but the patient may also have tenderness along the hip adductors and flexors. Examination of the hip is typically normal, although there may be some decrease in range of motion and discomfort with passive external rotation and abduction, particularly in the presence of a concomitant adductor strain.

Patients with stress fractures of the pubic symphysis present with diffuse pain throughout the lower hemipelvis and may experience radiation of pain to the groin or lower abdomen. Pain is increased with kicking, high-step marching, jumping, and running. As with stress fractures of the pubic ramus, the onset is typically insidious. Physical examination findings are similar, with tenderness at the pubic symphysis. Other areas that may produce symptoms with palpation, stretch, or resisted active motion include the hip adductors, the rectus abdominus, and the gracilis.

While treatment may be initiated on the basis of history and physical exam findings alone, initial evaluation with plain radiographs is typical. Radiographic changes may only be visible several weeks after the onset of symptoms, but attention should be paid to subtle periosteal reactions that may be seen in early films. Repeat X-rays at 2 to 4 weeks will typically show callus formation suggestive of bone healing.

In populations in which 2 weeks of relative rest while awaiting repeat radiographs is difficult, such as high-level athletes and military recruits, further imaging may be performed. Magnetic resonance imaging (MRI) offers the benefit of a clear delineation of bone and soft tissue pathology and is helpful in characterizing the nature and specific location of the fracture. MRI is also able to identify the presence or absence of a distinct fracture line. MRI is highly sensitive and specific, although it may not be as useful in identifying early lesions.

Nuclear scintigraphy (bone scan) is used to identify increased metabolic activity within the bone and, as such, can be helpful in the early diagnosis of stress fracture. Increased radionucleotide uptake is seen in any area of increased activity, such as tumors, infections, and metabolic diseases, and therefore, bone scans are not specific for stress fractures. Results should be carefully correlated with history and physical examination.

Treatment

Treatment for pelvic stress fractures includes a period of relative rest as well as a program to maintain cardiovascular fitness. The mainstay of treatment is avoidance of painful activities and may involve the use of crutches for initial management. The patient should be gradually returned to weight-bearing activities as tolerated through the use of swimming, stationary bicycling, the elliptical trainer, and other low-impact exercise regimens. A program of hip strengthening may be added to the rehabilitation program, with particular attention to the hip adductors, which often show some relative weakness and disuse atrophy.

The use of pain medications is controversial. Some practitioners feel that medicines may mask pain to such an extent that patients may participate in impact activities earlier than they should, which could result in delayed healing. Others raise concerns about data that suggest a slight delay in bone healing with the use of NSAIDs. Typical medications used include naproxen, ibuprofen, acetaminophen, tramadol, and, rarely, opioid analgesics.

Return to Sports

The final phase of rehabilitation should include sport-specific activities designed to challenge the patient in a safe and controlled environment. Total healing time for pelvic stress fractures is typically 6 to 8 weeks.

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See also Hip, Pelvis, and Groin Injuries; Hip, Pelvis, and Groin Injuries, Surgery for; Sports Injuries, Overuse

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PEPTIDE HORMONES

Peptide hormones are chemicals made up of amino acid chains. They are produced naturally by various glands in the body. Synthetic forms of several peptide hormones have been created and have a wide range of medical indications. Human growth hormone (HGH), erythropoietin (EPO), and insulin are examples of peptide hormones that have been abused by athletes to achieve a competitive edge in sports.

HGH is an anabolic (tissue-building) hormone that has become very popular recently among elite athletes as a performance-enhancing drug. It is a peptide hormone that is produced in the pituitary gland throughout a person's life. The highest levels of endogenous (naturally occurring) HGH are found during puberty and early adolescence.

Growth hormone has been shown to increase lean muscle mass and strength. It assists an athlete in recovering from injuries or strenuous workouts and is of particular interest for professional athletes who endure long, grueling seasons. It is banned in all professional sports and in international competition, but it is currently almost impossible to detect. It is likely used at all levels of competition, including high school athletics, although most amateur athletes may not be able to afford this expensive drug.

Athletes who use HGH for performance enhancement may be using 10 to 20 times the normal amount, and the long-term effects of this are still unknown. Potential risks include a significantly higher rate of joint pains, carpal tunnel syndrome, and diabetes. Increased skull circumference, peripheral neuropathy, hypertension, and behavioral changes have also been noted. There are also concerns that HGH may contribute to certain types of tumors.

EPO is produced naturally in the kidney and is a hormone that stimulates the bone marrow to make more red blood cells. A synthetic form of EPO has been abused by athletes in endurance sports to increase the number of red blood cells in their bloodstream, thereby increasing oxygen-carrying capacity. EPO is a banned substance in all competitive sports and carries significant health risks. The increase in red blood cells can lead to heart attacks, strokes, and blood clots.

Insulin is a peptide hormone that regulates the body's glucose (sugar) levels. It also has some anabolic, or muscle-building, properties. Insulin is produced naturally in the pancreas. Lack of insulin production or insensitivity to insulin action is the disease known as diabetes mellitus. Athletes who don't have diabetes have used insulin as a performance-enhancing drug because of its anabolic properties and its ability to slow the degradation of muscle tissue. In addition, it assists the delivery of fuel to muscle tissue, which may improve performance and stamina in endurance athletes. Serious side effects of inappropriate use include hypoglycemia (low blood sugar), seizures, and death.

Insulin and other hormones or medications certainly have an appropriate therapeutic role for many patients and athletes. There is a way for athletes to continue use of medications such as insulin and still compete. A Therapeutic Use Exemption is filed before competition. This documents the medical necessity with the athlete's local sports governing body. Sometimes therapeutic levels of these substances are monitored in and out of competition.

Hormones exist in a very delicate balance, often in minute amounts in normal physiology. Once in the bloodstream, they influence almost all tissues in the body and can also increase or decrease the levels of other powerful hormones. Athletes using hormones for performance enhancement have to be aware of the immense power of these chemicals and the potential consequences of their action. Abuse of these hormones can have serious immediate or delayed consequences, some of which are yet to be discovered.

Michael O'Brien

See also Anabolic Steroids; Beta Agonists; Beta Blockers; Blood Transfusion; Cannabinoids; Creatine; Doping and Performance Enhancement: A New Definition; Growth Hormone; Performance Enhancement, Doping, Therapeutic Use Exemptions

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Performance Enhancement, Doping, Therapeutic Use Exemptions

Enhancement of athletic performance has been attempted throughout human history. People have tried to overcome the limitations of the human body through training or by using artificial substances or methods. Although proper training can improve performance, there are natural limits to the degree of improvement that can be achieved. However, with alterations in the body's own chemistry, certain substances or methods can allow athletes to perform beyond the normal physiological limits. Pharmaceuticals can be used for different purposes from those originally intended. Many common medications that are used for sick patients are unfortunately abused and taken by healthy athletes with the sole purpose of improving their athletic performance, although these medications have the potential for doing irreversible damage.

Today, there are many technologies that can enhance human performance, from medications to genetic engineering. Some people believe that we have a right to modify our bodies; others fear that performance enhancement can be dangerous and only results in short-term gains while having long-term detrimental consequences. Unequal access to such enhancements is also feared if such practices were to become commonly accepted.

Performance-enhancing drugs are typically used by athletes, including recreational athletes, to improve in their specific sport. Over time, drug use has become increasingly sophisticated and difficult to detect. Many sports organizations have developed rules and regulations for the use of performance-enhancing substances. Although there is currently no single organization that governs all sports, the World Anti-Doping Agency (WADA) monitors all Olympic athletes as well as several independent professional sports. Many countries and Olympic sports have their own antidoping organizations that are affiliated with WADA. WADA, like many antidoping organizations, provides testing, education, research, and results management in the hope of preventing athletes from using banned substances and methods.

Anabolic steroids usually come to mind when people discuss performance-enhancing drugs. There are over a hundred different types of anabolic steroids, which makes it difficult to design a test to detect their use in athletes. Although many of the athletes who use these drugs are recreational weight lifters, many professional athletes try anabolic steroids at some point in their careers.

The many types of athletic performance–enhancing drugs include lean-mass builders, stimulants, painkillers, sedatives, diuretics, and masking agents. Having additional lean body mass is directly related to improved athletic performance. Anabolic steroids, beta-2 agonists, and human growth hormone have been shown to increase the growth of muscle while improving athletic performance. Increasing an athlete's alertness and aggression and reducing fatigue can improve athletic performance. Stimulants such as caffeine and amphetamines have long been used to improve athletes' strength and speed. Many times, pain is the rate-limiting step in improved performance. Medications that reduce pain can improve performance by allowing the athlete to go beyond the normal pain threshold. Over-the-counter medications such as ibuprofen and acetaminophen as well as prescription medications such as hydrocodone are often used. Shooting sports require a steady hand and heart, and sedatives and beta blockers are used to improve aim and reduce nervousness. Drugs such as alcohol, propranolol, and even marijuana are often tried. Competition among athletes is often determined by the size of the athlete, and remaining in a narrow weight range can be difficult. Diuretics are sometimes used by athletes to reduce water weight in order to remain in a certain weight class. Sometimes these drugs are used to dilute the urine to avoid detection of a number of banned substances. These masking agents are often used, so tests have been developed to detect these chemicals.

The term *performance enhancing* can sometimes be confusing because nonbanned substances such as vitamins, carbohydrates, and proteins can also improve performance. However, these substances can only improve performance within the body's normal capacity. Most banned substances improve performance beyond the physiological norms, which can be difficult to explain and understand. The reason why there are so many different antidoping organizations is because there is no current universal agreement on which substances and methods can and cannot improve performance. Testing ability is also widely variable from test site to test site.

Some athletes even use their own blood to improve performance through a method known as "blood doping." Athletes will have several pints of their own blood removed, stored, and then transfused into their body the day of a competition. This method will often double the amount of red blood cells present in the body while improving their ability to carry oxygen and, thus, will improve performance. As with many performance enhancers, blood doping is difficult to detect.

Doping

Doping refers to the use of performance-enhancing drugs in sports that ban certain substances and methods. Athletes use doping mostly to improve performance. However, doping is also becoming increasingly popular in recreational sports such as body building.

There are many forms of doping besides blood doping (discussed in the preceding section). Other substances include erythropoietin and anabolic steroids, which can improve athletic performance. Many international sports organizations consider doping unethical because of the risk to health, the unfair advantage it gives to the user over other athletes, and the negative impact it has on public perception. Many countries followed East Germany's experiments in the 1960s with anabolic steroids. Their athletes exceeded all expectations in performance and training, but this resulted in serious long-term side effects including cancer and sometimes early death. At that time testosterone, a male hormone, was given to both male and female athletes. Testosterone increases protein production, which results in bigger and stronger muscles. Unfortunately, it also increases the vocal cord size and deepens the voice as well as increases body hair production. Anabolic steroids are used today therapeutically to treat sick patients with muscle wasting, as in cancer and AIDS. When excessive amounts are used for an extended period of time, harmful effects can occur. These include increases in cholesterol levels, acne, high blood pressure, and liver and heart damage. The nontherapeutic use of anabolic steroids has been becoming increasingly popular in competitive sports. However, all major sporting bodies have banned the use of steroids both in and out of competition. Most governments consider anabolic steroids controlled substances and regulate their use. This has resulted in a black market, and these drugs are often smuggled into countries and sold illegally. The smuggled drugs are often impure and contaminated, which makes their use even more dangerous.

Previously, athletes started using the anabolic steroid tetrahydrogestrinone (THG) because it was undetectable by the standard antidoping test. Eventually, a test was designed to determine which athletes had used the drug, based on stored urine samples. Because of its widespread use, many athletes have been banned from future competition in many sports. Because of media involvement in high-profile cases such as Olympic gold medal winners, many athletes have been vigorously persuaded in and out of court to give up use of this drug.

The International Association of Athletics Federations was the first international governing body, in 1928, to ban participants from doping. Many other organizations soon followed. Until the creation of formal antidoping organizations, many athletes had used doping methods for years without having to face the consequences. Since the creation of WADA in 1999 and the Major League Baseball Drug Policy, athletes are no longer getting away with using banned substances. Removing these athletes from competition has leveled the playing field.

Drug use in sports involves many high-profile players and championships, including the World Weightlifting Championships, Tour de France, Olympic Games, World Ski Championships, and World Track and Field Championships. Many noted athletic stars were found guilty because of their involvement with the Bay Area Laboratory Co-Operative (BALCO), a supplement lab that confirmed negative drug testing results for athletes using banned substances. The lab founder subsequently was found guilty and had to do time in prison.

Antidoping programs try to preserve "the spirit of sport." These values include the following:

- Ethics, fair play, and honesty
- Health
- Excellence in performance
- Character and education
- Fun and joy

- Teamwork
- Dedication and commitment
- Respect for rules and laws
- Respect for self and other participants
- Courage
- Community and solidarity

WADA was established in 1999 by the International Olympic Committee (IOC) with support from governmental organizations, public authorities, and private bodies. Ultimately, WADA's mission is to control doping in sports with the assistance of the IOC, national antidoping organizations (NADOs), sports federations, and athletes. The United States Anti-Doping Agency (USADA) is the independent antidoping agency for the Olympic Movement in America. Formed in 2000, USADA started providing testing, education, research, and results management for U.S. Olympic, Pan Am, and Paralympic athletes. USADA is a signatory to the World Anti-Doping Code and has implemented the requirements to meet the code, including the separate Prohibited List.

In 1999, the 1st World Conference established WADA; in 2003, the 2nd World Conference adopted the WADA Code; in 2007, the 3rd World Conference revised the WADA Code, which came into effect on January 1, 2009. The purpose of the WADA Code revision was to leverage the experience gained to date and strengthen the antidoping programs.

The definition of doping is detailed and complex, so that it can be all-inclusive and rigorous enough to stand up in courts of law. Doping involves the following:

- Presence of a Prohibited Substance or its Metabolites or Markers in an Athlete's Sample
- Use or Attempted Use by an Athlete of a Prohibited Substance or a Prohibited Method
- Refusing or failing without compelling justification to submit to Sample collection after notification as authorized in applicable anti-doping rules, or otherwise evading Sample collection
- Violation of applicable requirements regarding Athlete availability for Out-of-Competition Testing, including failure to file required whereabouts information and missed tests which are declared based on rules which comply with the International Standard for Testing. Any combination of three missed tests and/or filing failures within an eighteen-month period as determined by Anti-Doping Organizations with jurisdiction over the Athlete shall constitute an anti-doping rule violation
- Tampering or Attempted Tampering with any part of Doping Control
- Possession of Prohibited Substances and Prohibited Methods
- Trafficking or Attempted Trafficking in any Prohibited Substance or Prohibited Method
- Administration or Attempted administration to any Athlete In-Competition of any Prohibited Method or Prohibited Substance, or administration or Attempted administration to any Athlete Out-of-Competition of any Prohibited Method or any Prohibited Substance that is prohibited Out-of-Competition, or assisting, encouraging, aiding, abetting, covering up or any other type of complicity involving an anti-doping rule violation or any Attempted anti-doping rule violation. (The World Anti-Doping Code, 2009)

Criteria for placing a substance on *The 2009 Prohibited List* include the following:

- Medical or other scientific evidence, pharmacological effect, or experience that the substance or method, alone or in combination with other substances or methods, has the potential to enhance or enhances sport performance
- Medical or other scientific evidence, pharmacological effect, or experience that the use of the substance or method represents an actual or potential health risk to the athlete
- WADA's determination that the use of the substance or method violates the spirit of sport described in the Introduction to the Code
- WADA's determination that there is medical or other scientific evidence, pharmacological effect, or experience that the substance or method has the potential to mask the use of other prohibited substances or prohibited methods

With a better understanding of doping, we can appreciate the true purpose of the WADA Code.

The Code aims to protect the athlete's fundamental right to participate in doping-free sport and thus promote health, fairness, and equality for athletes worldwide. It also aims to ensure harmonized, coordinated, and effective antidoping programs at the international and national levels for the detection, deterrence, and prevention of doping.

With the development of the new WADA Code, additional groups are being considered for doping violations. When a drug trafficking violation occurs, the penalty will be a minimum of 4 years of ineligibility. When minors are involved, it will be considered a particularly serious violation, and if committed by athlete support personnel, such as a coach, physician, or trainer, it will result in a lifetime of ineligibility. Athlete support personnel should educate and counsel athletes regarding antidoping policies and rules. Athletes may often find themselves in a situation where there may be a necessity to use a prohibited substance and will need to obtain approval through a Therapeutic Use Exemption (TUE).

Therapeutic Use Exemption

The TUE process provides a method for athletes to seek permission to use a prohibited medication that is medically necessary. However, athletes seeking permission to use certain beta-2 agonists for asthma or glucocorticosteroids by inhalation and intraarticular or local injection must use the Abbreviated Therapeutic Use Exemption. Both processes must be completed and submitted prior to participation in sports.

Ultimately, it is the athlete's responsibility to know what medications he or she is taking and whether these are prohibited or not. The purpose of the TUE is to ensure that athletes get the medical care they need while harmonizing the process across sports and countries. If the medication needed to treat an illness falls in the Prohibited List, the TUE may give authorization to the athlete to use these substances. TUEs are granted if

- the athlete would experience significant health problems if the prohibited substance or method were not used,
- the therapeutic use of the substance would not produce significant enhancement of performance, and
- there is no reasonable therapeutic alternative to the use of the prohibited substance or method.

International federations (IFs) and NADOs have processes that allow athletes with documented medical conditions to request a TUE. These organizations have a panel of independent physicians who are responsible for granting or declining such applications. In the case of international-level athletes, TUEs are submitted to their sport's IF or NADO if they are registered in their country's testing pool.

Athletes can apply for a TUE as follows:

- They must contact their IF or NADO and ask for a TUE application form.
- They must have their physician fill out the TUE application form and produce the required supporting documentation and forward it to the IF or NADO. Athletes should remember that according to the International Standards, the TUE application should be submitted at least 21 days before participating in an event.

The TUE is granted for a specific medication as well as a narrowly defined dosage and period of time. Athletes taking part in a competition should mention in the doping control form that a prohibited substance is being used and that a TUE has been granted.

Mark Troxler

See also Anabolic Steroids; Beta Agonists; Beta Blockers; Blood Transfusion; Cannabinoids; Creatine; Doping and Performance Enhancement: A New Definition; Doping and Performance Enhancement: Historical Overview; Doping and Performance Enhancement: Olympic Games From 2004 to 2008; Growth Hormone; Peptide Hormones

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Perineal Numbness and Erectile Dysfunction

Pudendal nerve compression syndrome, also known as Alcock syndrome, is a cluster of symptoms most commonly described in long-distance or long-term bicyclists. It is chiefly characterized by varying degrees of decreased sensation of the perineum, decreased glandular and penile sensation, weakened/absent erections, diminished/difficult orgasms, and occasional voiding symptoms. In this entry, perineal numbness and pain syndromes from injury to the pudendal nerve are discussed, particularly as they relate to erectile dysfunction (ED).

In recent years, many advances have been made in the understanding and medical treatment of ED. Classically, male sexual function has been defined in terms of the "point-and-shoot" model, with sacral parasympathetic (point) enervation responsible for erection and sympathetic (shoot) enervation responsible for ejaculation. However, this represents an oversimplification of the complex and somewhat ill-defined sensory, psychogenic, and motor pathways and interconnections orchestrating male sexual function. Proper function requires regulation and timing of voluntary and involuntary processes such as arousal, erection, pre-ejaculatory stiffing, orgasm, and ejaculatory peristalsis. Often the somatic sensory contribution, derived mostly from the pudendal nerve, is overlooked. A degraded perineal neurovascular supply can greatly diminish or abolish response to medical therapy. Along these lines, perineal paresthesia from any of several causes is often linked to ED.

The pudendal nerve courses from the S2-S4 nerve plexus, carrying sensory and motor fibers through the pudendal canal before giving rise to the inferior rectal nerve, the perineal nerve, and the dorsal nerve of the penis. The pudendal canal, also known as the Alcock canal, features prominently in the discussion of various perineal neurological conditions. The canal is formed by a duplication of the obturator fascia and carries the pudendal nerve and accompanying vessels along the lateral wall of the ischiorectal fossa. Depending on the location of pudendal nerve involvement along its course, the type, severity, and association of symptoms can vary.

Pudendal nerve compression syndrome is believed to result from chronic compression and irritation of the dorsal nerve of the penis distal to the Alcock canal rather than truly within it. Although several small studies have shown the rate of Alcock syndrome to be higher in cyclists than in other athletes, another found the rate to be the same for bikers and nonbikers. Several studies indicate a vascular component to hypoesthesia and ED, as well as nerve compression.

Numerous studies have been conducted with the intention of optimizing bicycle seat design, handlebar-to-seat geometry, and seating configuration. The treatment for Alcock syndrome is usually conservative management and stressor avoidance, with a large percentage of patients regaining satisfactory erectile function. The recovery process time frame is variable and depends on the duration of insult and patient compliance with therapy, but usually, return of sensation occurs within several months.

Bicycle-associated acute pudendal nerve injury can present with a range of symptoms and more closely resembles pelvic trauma. There is more often a vascular injury, and one study suggests that the resultant numbness and ED are related to endothelial damage to the hypogastric and cavernosal vascular beds. This patient population more commonly encompasses a younger "daredevil" type who has sustained an acute straddle injury, and the outcome may be progressive and permanent with aging. Paresthesia may be unavoidable for some of these patients, and the success of medical ED therapy is not known.

Pudendal nerve entrapment syndrome is a separate entity from compression syndrome. It is defined by the Nantes criteria and remains a clinical diagnosis of exclusion. In addition to the five required pain symptoms defining the condition, associated symptoms may or may not include pain with defecation, fecal incontinence, urinary frequency and voiding dysfunction, pain following ejaculation, difficulty achieving orgasm, and ED. One study suggests that the configuration of the sacrotuberous ligament may congenitally predispose some individuals to pudendal nerve entrapment. Management can be coordinated with a neurologist and may include a thorough workup to exclude other diagnoses.

Severe pelvic trauma and vascular malformations/dilations can cause perineal symptoms associated with sexual dysfunction; moreover, the treatment of these conditions can also lead to the same problem. For instance, pelvic fracture is itself frequently associated with acute neurovascular injury and may be the incipient cause of paresthesia and ED. On the other hand, treatment related to acute trauma can be the cause. For instance, pelvic fracture and penetrating trauma are often accompanied by significant hemorrhage, requiring unilateral or bilateral embolization of the internal iliac artery, with resultant pelvic claudication, numbness, and ED. Likewise, patients unable to undergo open repair of an abdominal aortic aneurysm can now avail themselves of endograft placement. In many cases, unilateral or bilateral internal iliac artery embolization may be necessary for technical success of the endograft seating and function. In this patient population, the resultant perineal sequelae and ED have been mixed in several small, relatively short-term studies. In these cases, the success of medical management of the ED component is unclear and may warrant elucidation.

Male sexual function depends on sensory and motor enervation, psychological and somatic triggers, and adequate cardiac and vascular health. In many cases of dysfunction, medical therapy has made great strides in restoring erections. However, in many instances in which perineal/genital sensory input is impaired, by either neurologic or vascular insult, surgical correction may be the remaining option for correction of ED.

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Periodization

Periodization is a system of training that is divided into specific periods of time each with a purpose. It is based on a scientific understanding of adaptation that requires gradually increasing repetitive stimuli with required rest to build toward peak performance. While there are various formats of periodization, the general plan includes phases of rest/transition, preparation, base, build, and taper to maximize performance.

Historical Background

In classical antiquity, the Greeks first used periodization training, with very simple plans of increasing training loads over time, in preparation for the Olympic Games.

In the 20th century, the Russians advanced periodization during the period from the 1920s to the 1940s by dividing training into different phases: general, preparatory, and specific. Previously, the training was to maintain the same constant stresses year-round. The general stage of training, often lasting for about 2 months or so, was supposed to develop the heart and lungs. The goal of preparatory training, also 2 months in duration, was to increase muscle strength and endurance. The specific phase, of about 8 months, prepared an athlete for a particular sporting event by emphasizing extensive practice of the precise movements involved in the sport. Some periods of training were made easier to rest the body and allow it to grow stronger.

Types of Periodization

While there are various models and variations of periodization training, most Western coaches have primarily focused on a model in which the volume of general preparation decreases as the intensity of and emphasis on technical training for specific preparations increase, producing peak performance during the competition phase. Tudor Bompa, considered the father of periodization, refined the ideas of Russian sports scientists in the early 1960s. His book *Theory and Methodology of Training* describes the various periodization patterns included in this classic wave cycle, starting with aerobic base, adding intensity, and building to peak.

An alternative to the wavelike periodization pattern is *step periodization,* in which training loads and intensities are changed abruptly, rather than smoothly and progressively from workout to workout, and in weekly and monthly cycles. In this plan, series of easier workouts are alternated with groups of intense efforts with very little break between the difficult sessions. Some studies have shown this method to be fairly effective in developing muscular strength for sports such as weight lifting.

In *skill strength periodization,* athletes spend an extensive amount of time perfecting their technical skills during the preparatory phase of training, prior to embarking on the development of strength and/or endurance. Once athletes become skilled (e.g., a swimmer or runner with efficient form), they can optimally use their increasing strength to boost performance. The goal is not to waste the increased strength on inefficient movements but to have it directed only toward correct patterns of motion.

Emphasis periodization is a training plan that is divided into 4- to 10-week time blocks or mesocycles, with each block having a specific emphasis or concentration. Each emphasis acts as a foundation for the following period. For example, a runner would first develop running-specific strength before power or economy prior to $\dot{V}O_2max$ (peak oxygen uptake). All the emphasis periods have to be completed prior to a targeted race.

Studies of periodization have been difficult since most studies have been limited to short periods of time. High dropout rates and lack of adherence also make it difficult to have high-quality studies to compare methods.

Basic Components of Periodization

The basic components of periodization include the following:

Microcycle: A number of training sessions form a recurrent unit, that is, a hard-easy-rest pattern, typically lasting 5 to 10 days.

Mesocycle: This refers to a block of training consisting of some number of microcycles, which emphasizes the attainment of a particular goal, for example, preparation for and completion of a very important marathon, and usually lasts 4 to 12 months.

Macrocycle: This consists of a number of different microcycles and covers a period from many months up to 1 year.

Individuality: Different athletes have different needs. Blocks may need to be devoted to muscular strength, lactate threshold, or $\dot{V}O_2max$ (peak oxygen uptake) depending on the weaknesses of a particular athlete. For example, the needs of a novice and an experienced athlete are very different. A new athlete may

Table 1 Phases of Periodization

Phase	*How Long? (Weeks)*	*Frequency*	*Duration*	*Intensity*	*Volume*
Preparatory	3–6	High	Short to medium	Very little	Low
Base	12–24	High	Medium to high	Moderate	Moderate to high
Build	4–8	Moderate to high	High	Heavy	Moderate
Peak/race	3–5	Moderate	Short	Heavy	Low

not be able to tolerate initial high volumes of training because he or she has not had the years of muscle adaptation required to tolerate such volumes. Lack of individuality in a training plan would result in soreness, impaired adaptation, possible injury, and reduced motivation. Instead, a new athlete may need more early emphasis on technique.

Periodization involves many variables, including

- frequency (how often you train),
- duration (how long you train in one session),
- volume (how much you train in a given week or cycle),
- intensity (how hard you train at any given time), and
- taper, which will help you reach your peak for the key race(s) you are targeting.

Rest or Transition Phase

The first phase of periodization, generally, is rest. The human body needs restoration periods to recover from periods of stress. This is a critical component of periodization, but it is often ignored by athletes of all ability levels. To improve performance, rest is needed.

The difficult part is how often a full recovery is needed and how long the recovery period should last. Top athletes seem to benefit from 1 month away from training each year.

Rest or the word "off" can mean different things. This is an opportunity to develop or re-aquaint oneself with other interests and hobbies and to take part in activities such as hiking or alternative sports that are not usually enjoyed during serious training. Some athletes do absolutely no training during this period, while others spend their "off" season running at a moderate pace at least a couple of times a week.

The goal, however, is to allow the body to become completely recovered and restored before resuming training. A study by Michael Warhol at Harvard Medical School found extensive damage in marathoners' leg muscles immediately after a marathon that took 4 weeks or more to recover from. Damaged muscle fibers and cell membranes, degenerated mitochondria, and damaged blood vessels were found.

Preparation Phase

The preparatory phase usually lasts 3 to 6 weeks. During this phase, the focus is on drills and on learning the technique for each sport. Strength is built to reduce the risk of injury from more intense training later in the year. The duration of workouts during this time is short and the intensity low. It is a time for the body to readjust to training. Strength training also offers benefits of improved biomechanical stability (especially if there previously were deficits), improved efficiency with improved technique (especially in sports where technique is important, such as swimming), and increased resistance to fatigue.

Base Phase

The base phase is one of the most important phases, especially for the endurance athlete. It can last from 12 to 24 weeks. The longer this phase lasts, the greater the aerobic fitness developed. This period can be shorter for endurance athletes who have trained or raced for many years and thus have had years of fitness, raising their base level of aerobic fitness. The base phase is literally the foundation of the entire year's training.

Typically, the base period itself will have blocks of 3 to 4 weeks, with each block progressively increasing in duration and distance. The training is entirely aerobic, with little to no intensity. The long workouts are gradually increased in frequency.

Build Phase

The build phase builds on the aerobic fitness developed in the base phase. This phase usually lasts 4 to 8 weeks and comes right before the targeted race. Volume will usually drop as intensity increases, although sometimes it may stay the same. But while the overall volume typically drops, the long workouts should be near all-year highs.

More workouts are focused on race pace or faster in order to prepare more for goal race conditions. Interval workouts are added to improve lactate threshold, again to simulate the intensity of racing and hard efforts with fatigue such as toward the end of a race. Intensity builds during the cycles.

Peak or Taper Phase

After all the hard work of the preparation, base, and build phases, the taper phase is physically quite easy but mentally very difficult. Many athletes never find the magic formula to make the perfect transition from their training to the race. Typically, over 2 weeks (and the duration is longer for a longer event), the volume is decreased, allowing the body to recover.

During this phase, there are still sessions of high intensities that match the pace of the race, but they are short. This phase is very individualistic. It is tempting for an athlete to continue to train during this period at a higher level than ideal due to the fear of losing fitness. To add minutes to a session or increase the number of sessions during this phase would be a mistake.

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See also Aerobic Endurance; Cardiovascular and Respiratory Anatomy and Physiology: Responses to Exercise; Conditioning; Core Strength; Cross-Training; Exercise Prescription; Exercise Programs; Fitness Testing; Gender and Age Differences in Response to Training; Interval Training/Fartlek; Performance Enhancement, Doping, Therapeutic Use Exemptions; Physiological Effects of Exercise on Cardiopulmonary System; Principles of Rehabilitation and Physical Therapy; Speed, Agility, and Speed Endurance Development

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Peroneal Strain

The peroneus muscles work together to turn the foot outward (evert) and also provide stability. These muscles are necessary for side-to-side movements and are commonly injured in sports such as tennis, basketball, running, and dance. Injury to the peroneal tendons is a relatively underdiagnosed injury and not an uncommon source of lateral ankle pain. The true incidence is not known. It is often a consequence of what the patient perceives to be a lateral ankle sprain injury, although it can occur independently. As with many problems in sports medicine, injury to the peroneal tendons may be the result of an acute event, or it may occur in a chronic fashion.

Anatomy

There are generally two peroneal muscles—the peroneus longus and peroneus brevis—that originate on the outside (lateral) part of the lower leg. A small percentage of the population has an additional or accessory peroneus muscle, the peroneus quartis. The peroneus longus begins high on the fibula, while the peroneus brevis originates from the lower two thirds of the fibula. At the end of the muscle, just before the lateral ankle bone (malleolus), the muscular part becomes tendon, and the two tendons come together in a sheath. As the tendons course around the ankle bone, they enter a fibro-osseous tunnel, which helps in holding them in place as they make this turn. This tunnel is called the retromalleolar groove and is covered by connective tissue called the superior retinaculum. This is the primary restraint keeping the tendons in place in the groove. Beyond the ankle, the tendons split from their sheath and tunnel, and the peroneus brevis inserts on the outside of the midfoot (tuberosity of the fifth metatarsal), while the peroneus longus travels along the undersurface (plantar surface) of the foot and inserts onto the first metatarsal.

Causes

Tendinopathy and Tears

Peroneal tendinitis and tenosynovitis are acute inflammatory conditions that often occur in areas where the tendon comes into contact with the bony structures or the retinaculum as it turns along its course. It is usually due to repetitive activity, especially if the activity follows a period of relative inactivity. As with other overuse injuries, any change in the intensity, frequency, or duration of sports or exercise training may be a contributing factor. A single isolated traumatic event can also be the cause.

Tendinosis is a chronic condition that can develop from repetitive microtrauma. It may be characterized by degenerative changes that result from mechanical friction and shearing injury. There may be fraying, split tears, or abnormal thickening of the tendon. A complete tear or rupture can also occur, usually associated with chronic tendinosis or chronic ankle instability. A nonhealing longitudinal tear of the tendon can be a cause of persistent lateral ankle pain.

Tendon Subluxation

Subluxation of the tendon can occur when the tendon's restraining structures, especially the superior retinaculum, are disrupted. The tendon then moves or snaps out of its place behind the ankle. This may occur as a result of an acute injury when the ankle is forced into extremes of plantarflexion or dorsiflexion and the peroneal muscle reflexively contracts. A lateral ankle sprain can occur at the same time. With chronic subluxation, the tendon moves or snaps out of its place with walking or running but especially with cutting. This may occur in patients with chronic ankle instability from multiple prior ankle sprains. In some, this may not be symptomatic at all, while in others it can be very painful and cause significant dysfunction.

Diagnosis

History and Exam

Peroneal tendon disorders present with pain along the outside of the ankle (lateral side). In tendinopathy, there is often a history of repetitive overuse. On examination, there may be swelling and warmth along the course of the tendons, and pain is elicited when the foot is turned inward (inversion) and down (plantarflexion) or when the patient moves it upward and outward against resistance (dorsiflexion and eversion). With tendinosis or tears, there may be swelling but not warmth. The area along the tendon is tender on palpation, and there may or may not be weakness noted in the ability to evert the foot.

In a patient with an acute ankle injury, it may be difficult to evaluate for subluxation until the swelling improves. The area is tender, and the ankle may be unstable. Movement and location of the tendon can be seen when the patient moves the foot in dorsiflexion and eversion. With chronic subluxation, there may be a history of snapping or popping along the outside of the ankle. Pain occurs as with acute subluxation, mostly when the patient is asked to actively point the foot up and outward. The tendon may be seen moving from its place behind the ankle when observing the patient's gait. Often, and most helpfully, the subluxating tendon and its symptoms can be reproduced on exam by having the examiner place his or her fingers over the tendon as it sits just behind the lateral malleolus and then ask the patient to repeatedly dorsiflex and plantarflex the foot.

Imaging

Plain X-ray films are helpful in evaluating a possible fracture of the bone in an acute injury. If imaging is necessary for evaluating tendon injury, magnetic resonance imaging (MRI) is the test of choice. Of note, the role of dynamic ultrasound imaging looks promising for diagnosing significant tears of the peroneal tendon in the office setting.

Management

Nonoperative

Treatment of peroneal tendinitis involves rest from the offending activity, ice, and nonsteroidal anti-inflammatory drugs such as ibuprofen. This is generally successful and is followed by gradual return to activity.

Tendinosis and tears can usually be treated nonoperatively, although they may require 4 to 8 weeks of immobilization and limited weight bearing in a boot or short leg cast. Physical therapy should then be directed at strengthening, stretching, and proprioceptive work in the foot, ankle, and lower leg. Some people with peroneal tendon disorders have abnormal foot mechanics and may need specially made orthotics.

Operative

In the non–high-level athlete, a trial of nonsurgical management for a peroneal tendon tear may be reasonable; if nonoperative treatment fails after 6 to 8 weeks, surgery may be indicated. This typically involves debridement of the tendon and repair when possible. A rupture may require grafting or, rarely, a tendon transfer.

Some patients with symptomatic acute or chronic subluxation who do not respond to aggressive nonoperative management may opt for surgical repair. In acute injuries, the superior retinaculum is often lifted off the bone and must be reattached after the tendon is relocated. There are many surgical approaches to chronic subluxation, all of which attempt to not only relocate the tendon but also identify and correct anatomic variations that predispose to the subluxation. Depending on the procedure, cast immobilization for 2 to 6 weeks postoperatively may be necessary. Physical therapy is then implemented for strengthening and proprioceptive training to restore and maximize function.

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See also Ankle Injuries; Peroneal Tendinitis; Strains, Muscle

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Peroneal Tendinitis

Peroneal tendinitis is a source of pain in the lateral (or outer) portion of the foot and ankle. A tendon is a strong piece of fibrous, connective tissue that attaches the muscle to the bone. The peroneals are made up of two muscles—the peroneus longus and peroneus brevis. These muscles of the lower leg play an important role in moving the foot in an outward direction, known as eversion. Tendinitis refers to inflammation of the tendon, which is thought to be the source of pain. There is a common sheath that surrounds the tendon, and if this becomes inflamed, it is referred to as a tenosynovitis. When this injury becomes chronic, there are significant degenerative changes within the tendon. This condition is referred to as a tendinosis or tendinopathy. Therefore, it is common to see this injury described as such. The injury may be induced by trauma or, especially in athletes, may be the result of overuse. Runners, dancers, and skaters are especially at risk for this problem.

Anatomy

The peroneal muscles are the primary evertors of the foot. This means that they are responsible for moving the foot in an outward direction. The peroneus longus and peroneus brevis muscles both give rise to their tendons just above the lateral malleolus, the bony protuberance on the outer portion of the ankle (see Figure 1). The tendons are both contained within one common sheath, or covering. This traverses behind and then beneath the lateral malleolus and continues along the outer portion of the foot. In the area of the lateral malleolus, the common tendon sheath is anchored by fibrous attachments. The peroneus brevis tendon then inserts at the base of the fifth metatarsal, the bone that leads up to the fifth toe. The peroneus longus tendon courses along the cuboid bone in the middle of the foot and then inserts at the base of the first metatarsal, a bone on the inner half of the foot that is at the base of the big toe. Apart from eversion, the peroneals also play a role in plantarflexion (moving the foot downward) and abduction (moving the foot away from the body) of the foot.

Causes

Pain caused by the peroneal tendon may result from multiple etiologies. Overuse of the tendon leads to tendinitis because of the excessive amount of stress placed on the tendon with activity. This leads to inflammation of the tendon, which causes pain. Ongoing stress can lead to degenerative changes, resulting in chronic tendon dysfunction. Therefore, in the absence of treatment, symptoms may be commonly present for many weeks or months without resolution. Any running athlete can develop this condition, as can dancers and skaters. One study of elite mountain road racers revealed that more than 10% had symptoms of peroneal tendinitis that were present for more than 3 months. This has led to the belief that running on uneven ground can predispose one to this condition. Although it is unclear if any specific age-group is at risk, some suggest that women above 50 years have a higher incidence of peroneal tendinitis and that excessive wearing of high heels may be a risk factor. Other causes include anatomical abnormalities, peroneal tendon subluxation, ankle instability, and prior ankle surgery.

Less commonly, the tendon will undergo subluxation or a shift in position. The tendon sheath is normally tethered to a groove behind the lateral malleolus. However, underlying anatomical abnormalities or an acute injury can lead to disruption of the attachment and subsequent subluxation. The acute injury occurs when the foot is subjected to a violently forced upward motion. Downhill skiers are at risk for this often misdiagnosed injury. Complete rupture of the tendon is another uncommon presentation of peroneal tendon pain. This may occur when the foot is violently moved in a downward and inward motion that stretches the tendon(s) to the point of failure.

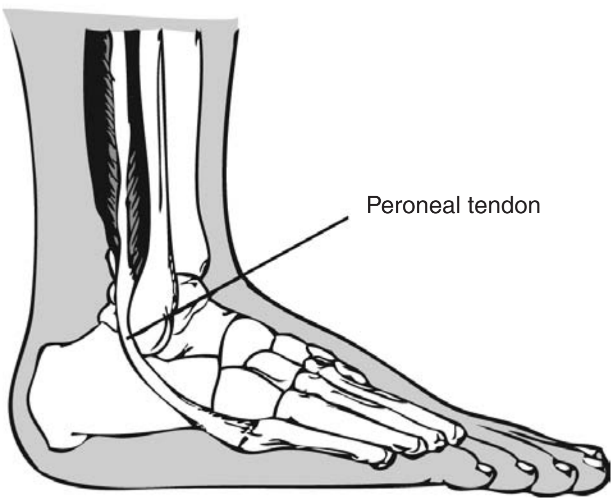

Figure 1 Peroneal Tendon

Source: Jonathan A. Becker, M.D., University of Louisville.

Note: An overview of the anatomy of the peroneal tendon showing its distribution and insertion into the fifth metatarsal.

Symptoms

The hallmark of peroneal tendinitis is the presence of lateral ankle and foot pain in the region of the peroneal tendon. Symptoms are most commonly felt in the area behind the lateral malleolus but may occur anywhere along the course of the tendon. Pain may be present for varying durations, often many months, and may or may not have been caused by a traumatic episode. Generally, the pain is related to activity and relieved by rest. Severity can be variable as well, ranging from mild to debilitating. Swelling is a common but inconsistent finding on exam. Signs of inflammation, such as warmth or redness, are less common. Certain motions, specifically moving the foot in an outward direction, can initiate the pain. In more advanced cases or those with ruptured or subluxed tendons, any weight-bearing activity can be painful. Those with peroneal subluxation may report a popping sound that precedes the pain symptoms.

Diagnosis

Typically, the diagnosis of peroneal tendinitis is made on the basis of the patient's history and physical examination. As previously mentioned, the typical history is that of lateral foot and/or ankle pain that worsens with activity. The exam will reveal tenderness in the distribution of the peroneal tendons, which may be a solitary, discrete area but can be more diffuse. Pain can be elicited with foot eversion, and the examiner can provide resistance to aid in re-creating the symptoms. Dorsiflexion of the ankle (moving the foot upward) against resistance may also elicit pain. Swelling is a common finding and may be indicative of a more severe injury. Redness and warmth are signs of acute inflammation. Signs of ankle instability are frequent as this may precipitate peroneal tendon problems.

In the case of peroneal tendon subluxation, the patient may have the ability to spontaneously move the tendon out of its normal position. The examiner may elicit subluxation by forcing the foot upward and outward. In cases of subluxation or rupture, there may be marked pain or swelling and associated weakness of the peroneal muscles. However, these findings may be rather subtle and the presentation indiscernible from more benign injuries.

X-rays are of little benefit in visualizing the peroneal tendons but may be useful in ruling out other common causes of lateral ankle pain, such as fractures of the lateral malleolus. Imaging of the foot can be used to rule out fractures of the base of the fifth metatarsal, where the peroneus brevis inserts. Magnetic resonance imaging (MRI) can be used to delineate the appearance of the tendon. Complete ruptures are well visualized, but minor longitudinal tears of the tendon, subluxation, and signs of tendinitis are often missed on an MRI scan.

Treatment

Regardless of the severity of the symptoms, initial management will be similar for most cases of peroneal tendinitis. Relative rest from the offending activity and frequent application of ice will allow for symptom control. Nonsteroidal anti-inflammatory drugs are helpful in pain reduction and may be particularly beneficial in cases of tenosynovitis. Elevation will reduce swelling. Braces or splints can be used to provide ankle support, as many patients will have concomitant ankle instability. For athletes, this can also be accomplished with taping. An exercise program that promotes stretching of the posterior calf muscles and strengthening of the foot and ankle muscles will provide rehabilitation. This not only will strengthen the peroneal muscles but also will help provide support for an unstable ankle.

In more severe cases, crutches or a short leg walking cast may be used to alleviate symptoms for those with debilitating pain or pain with routine activities of daily living. Physical therapy may be employed to provide an exercise program, and modalities such as ultrasound or iontophoresis (the introduction of pain-relieving medications through the skin) may be used. There is conflicting evidence regarding the benefits of those treatments. For cases with significant evidence of inflammation or those unresponsive to more conservative measures, a local steroid injection may be employed to relieve pain. However, these injections place the patient at risk for tendon rupture, prompting some experts to recommend against them. The time course for resolution of symptoms, especially in more severe cases, can vary from weeks to months. Generally, the longer those symptoms have been present at the time of presentation, the longer it will take for recovery. Return to activity is based on the level of discomfort. Once any deficits in strength and range of motion have been regained, patients can advance their activity level as symptoms allow.

Surgery is reserved for severe cases that are refractory to more conservative measures. The damaged portion of the tendon can be excised and the remaining free ends then sutured back together. It is recommended that even in cases of complete rupture or subluxation, patients undergo a trial of conservative treatment before surgery is employed. However, those with chronic symptoms of subluxation, especially active people, will often require surgical repair.

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See also Ankle Injuries; Sports Injuries, Overuse; Tendinitis, Tendinosis

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Peroneal Tendon Subluxation

Peroneal tendon subluxation is a relatively uncommon condition in which the peroneal tendons slip out of the retromalleolar groove during tendon loading. It was first described in 1803 in a ballet dancer, but it is also commonly associated with other sports such as skiing, ice skating, soccer, basketball, rugby, and gymnastics, and with motor vehicle accidents. The superior peroneal retinaculum is the primary restraint to peroneal tendon subluxation. Tearing or stretching out of this retinaculum makes it an incompetent restraint to subluxation of dislocation. This can occur as a result of an acute dislocation or after chronic tendon subluxation. Because of the high failure rate associated with nonoperative treatment, there has been a trend toward primary surgical management of acute peroneal tendon subluxation.

Anatomy

The peroneus longus and brevis are contained, with the superficial peroneal nerve, in the lateral compartment of the lower leg. The peroneus longus originates on the lateral aspect of the upper two thirds of the fibula and inserts onto the base of the first metatarsal and the lateral aspect of the medial cuneiform. The peroneus brevis originates on the lateral aspect of the lower one third of the fibula and inserts on the tuberosity of the base of the fifth metatarsal. Approximately 4 centimeters (cm) proximal to the distal tip of the lateral malleolus, the two tendons enter a common synovial sheath and pass posterior to the lateral malleolus in the retromalleolar groove.

The peroneal tendons are maintained within the retromalleolar groove by the superficial peroneal retinaculum (SPN). The SPN is the primary restraint to peroneal tendon subluxation. The SPN is a fibrous band of tissue, approximately 1 to 2 cm wide. It extends from the posterolateral aspect of the fibula and inserts on the lateral aspect of the calcaneus onto the peroneal tubercle. In some people, the SPN has an additional attachment onto the Achilles tendon sheath. Distal to the lateral malleolus, the tendons pass through the inferior peroneal retinaculum.

Proximal to the lateral malleolus, the peroneus brevis tendon lies deep to the peroneus longus. Distal to the lateral malleolus, the peroneus brevis tendon lies anterior to the peroneus longus. This relationship is important to understand when attempting to identify the correct tendon during surgical procedures.

The blood supply for the peroneal tendons is from the posterior peroneal artery and from the branches of the medial tarsal artery.

The peroneus brevis tendon is the primary evertor of the foot. It also assists in abducting the foot and plantarflexing the ankle. The peroneus longus everts the foot, plantarflexes the first ray, assists in ankle flexion, and helps stabilize the medial column of the foot during stance.

Certain anatomic variations are thought to predispose individuals to peroneal tendon subluxation. These include variations in the shape of the retromalleolar groove, a low-lying peroneus brevis muscle belly, or an accessory peroneus quartus muscle.

A shallow retromalleolar groove may contribute to peroneal tendon instability. A low-lying peroneus brevis muscle or an accessory peroneus quartus muscle can cause stenosis in the retromalleolar groove and can lead to attenuation of the superior peroneal retinaculum.

Etiology

Acute peroneal tendon dislocation presents following a traumatic ankle injury where the superior peroneal retinaculum has ruptured or become attenuated. Chronic peroneal tendon subluxation or dislocation may be associated with an untreated dislocation, or symptoms may have developed over a period of time with no specific traumatic event. Chronic peroneal tendon instability can be associated with lateral ankle instability, a cavovarus foot, a split in the peroneus brevis tendon, a lax superior peroneal retinaculum, or a shallow retromalleolar groove (Figure 1).

Clinical Presentation

Patients with peroneal tendon instability often localize pain to the posterior aspect of the lateral malleolus. Occasionally, they will describe a painful snapping or popping sensation within the ankle range of motion. After an acute event, the ankle is usually swollen and tender and may be ecchymotic (bruised). Tendon subluxation can occasionally be observed when the patient walks but is more commonly reproduced with active ankle dorsiflexion and eversion or circumduction of the foot.

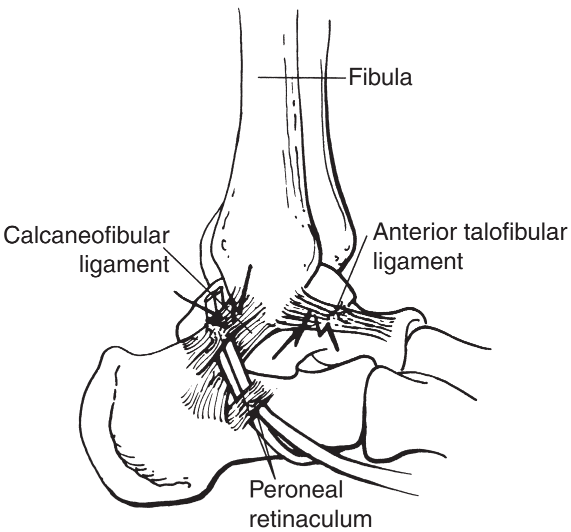

Figure 1 Peroneal Tendon Subluxation

Notes: Peroneal tendon subluxation occurs when the tendons slip forward in and out of the retromalleolar groove through which they travel. This may begin following an inversion sprain in which the peritoneal retinaculum sustains a tear.

Safran described a test to elicit tendon instability. The test is performed with the patient prone and the knee flexed to 90°. The examiner then resists the patient's attempt to dorsiflex and everts his or her ankle.

It is also important to perform an anterior drawer test and a talar tilt test to rule out lateral ankle ligamentous instability.

Imaging

Imaging studies of a patient with peroneal tendon subluxation should include weight-bearing anterior-posterior (A-P) and lateral radiographs of the foot, as well as A-P, lateral, and mortise views of the ankle. The peroneal tubercle and retromalleolar groove are best evaluated with a Harris-Beath heel view. The Harris-Beath heel view can also be used to evaluate for a cavovarus foot, which may increase the risk of peroneal tendon subluxation.

A small avulsion fracture of the lateral malleolus (fleck sign) is pathognomonic for a tear of the superior peroneal retinaculum.

Magnetic resonance imaging (MRI) is useful in evaluating the soft tissues of the foot and ankle, such as the condition of the peroneus brevis tendon. Other conditions that may be contributing to the patient's symptoms can also be ruled out. An MRI scan with the foot in dorsiflexion may demonstrate tendon displacement.

Treatment

Nonoperative

Nonoperative treatment is associated with a high rate of recurrence. It can sometimes be successful, however, in treatment after an acute dislocation. Treatment consists of immobilization in a short leg cast with the foot in neutral to slight inversion to encourage the superior peroneal retinaculum to heal to its attachment site on the posterolateral aspect of the fibula. A felt pad may be placed over the lateral malleolus prior to casting to hold the tendons within the retromalleolar groove while the retinaculum heals. After casting, aggressive physical therapy should be used to strengthen the muscles of the foot and ankle prior to return to activities.

Operative

Because of the high percentage of failure of attempted nonoperative management in high-demand individuals, there has been a trend toward primary surgical management of acute peroneal tendon dislocation.

Several approaches have been developed, including anatomic reattachment of the peroneal retinaculum, reinforcement of the retinaculum with local soft tissue, groove-deepening procedures, bone-block procedures to create a mechanical block to subluxation, and rerouting the peroneal tendons behind the calcaneofibular ligament to stabilize the ligaments within the retromalleolar groove.

With any of these procedures, it is important to address the findings that may be contributing to peroneal tendon instability, such as debriding a low-lying peroneus brevis muscle belly, excision of a peroneus quartus muscle, or correction of varus hindfoot alignment.

After Surgery

After surgery, the patient is placed in a weight-bearing cast for 4 weeks in a position of neutral dorsiflexion and slight eversion. Physical therapy is started after the cast is removed. Gradual return to sports is allowed 3 to 4 months after surgery.

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See also Ankle Injuries; Sports Injuries, Acute

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Personality and Exercise

The history of personality can be traced to Hippocrates (ca. 460–377 BCE), and behaviors such as physical activity were linked to this original theorizing. Academic research on personality and exercise behavior has been sporadic for 30 years, with a recent increase in the late 1990s onward. This mimics the general upward focus on personality research as measures have improved and evidence has mounted to show that personality traits are stable and cross-cultural and display a finite taxonomy. Personality traits are considered as enduring and consistent individual-level differences in tendencies that show consistent patterns of thoughts, feelings, and actions. Many researchers further theorize that personality has a biological/genetic basis and this constitutes the focus of the personality and exercise relationship; that is, personality research is attempting to evaluate whether people have a predisposition for adhering to regular exercise behavior.

Models of Personality

Two popular frameworks (or taxonomies) dominate the extant research on personality and exercise. The first is Eysenck's three-factor model of traits: extroversion, neuroticism, and psychoticism. Extroversion represents the tendency to be social, assertive, busy, energetic, and positive in affect, while neuroticism represents the tendency to exhibit anxiety, depressed mood, self-consciousness, and vulnerability. Psychoticism, in contrast, represents a tendency toward risk taking, impulsiveness, irresponsibility, manipulativeness, and sensation seeking. The other popular taxonomy is known as the five-factor model of personality and has had considerable support as a basic structure of personality. In addition to the extroversion and neuroticism traits of Eysenck's model, this model includes the traits of agreeableness (e.g., the tendency to be perceptive, creative, reflective, and appreciative of fantasy and aesthetics), openness to experience (e.g., the tendency to be kind, cooperative, altruistic, trustworthy, and generous), and conscientiousness (e.g., the tendency to be ordered, dutiful, self-disciplined, and achievement oriented). These factors are considered orthogonal (i.e., uncorrelated), but extroversion and neuroticism are typically negatively related, while extroversion and conscientiousness are positively related.

Exercise and Personality Relationship

Overall, exercise behavior is positively correlated with extroversion and conscientiousness and negatively related to neuroticism. These are small effects; thus, the associations are reliable perhaps at a population level but contribute to only a small piece of the puzzle when attempting to explain why some people exercise while others do not. Agreeableness, openness to experience, and psychoticism are not related to exercise in a reliable way. The relationships between personality traits and exercise also depend on the mode of activity. The extroversion relationship, for example, appears to be more for vigorous or moderate-intensity exercise but does not hold for light activities or regular leisure-time walking. There is some indication that gender effects (more pronounced for females than for males) and cultural effects (North Americans seem to have a larger extroversion effect than do people from the United Kingdom) may be occurring, but this idea has not undergone enough formal testing at present. There is also some evidence that personality effects may be most influential during regular exercise transitions (e.g., adoption, resumption). Some evidence has demonstrated quite large effects for personality factors of neuroticism, extroversion, and conscientiousness when participants are organized by maintenance, adoption, or cessation exercise patterns. This suggests that personality may have both predisposition and acquisition effects on behavior change and regulation.

Current Research

Current research is now focusing on the mechanisms for how personality may influence regular exercise. There is evidence that extroversion's more specific subtrait of activity (the tendency to be busy, energetic, and talkative and have a preference for a fast pace) may be the critical link with exercise. In some cases, this trait has explained exercise behavior regardless of an individual's initial intentions. Thus, other expressed subtraits of extroversion, such as sociability and positive affect, may be less important to exercise than activity (or physical extroversion). Another line of research has focused on how personality and exercise motivation interact. Some research has indicated that personality may be linked with exercise through attitudes (i.e., the evaluation of exercise and its benefits vs. costs) and perceptions of control (i.e., the perceived capability to perform regular exercise). In this case, extroverted, conscientious, and emotionally stable people see more value in performing exercise and consider it more under their control than their introverted, less conscientious, or neurotic counterparts. This perceived value and control subsequently lead to stronger motivation and eventual performance of regular exercise.

Another interesting line of research has focused on how personality may affect the translation of exercise intentions into behavior. Exercise intention has garnered support as the proximal predictor of behavior, but a large gap between the two is still present; indeed, most of the populace has some intent to exercise regularly, but only half of these people actually follow through on these intentions. Personality research has demonstrated that conscientiousness, and sometimes extroversion, interact with this intention-behavior relationship. That is, people low in conscientiousness and extroversion have a lower intention-behavior relationship than those high on these traits. The suggested mechanism for this link is the basic premise that conscientious people are naturally more dutiful, organized, and self-disciplined, which allows them to fulfill their initial intentions. For extroversion, it has been suggested that extroverts are more likely than introverts to find themselves in situations (social, active, etc.) where they can act on their intentions.

The practical application of personality and exercise research has seen less attention. If personality is stable and not easy to change, it suggests that physical activity promotion efforts via personality may not be feasible. One possibility, however, is that exercise preferences could be matched or targeted by personality, and this successful combination could aid in improving adherence. There are some differences in exercise preferences by personality; most notable is that extroverts prefer to exercise in groups, while introverts have a preference for exercising alone. Another possibility is that personality characteristics could be used as markers of people at risk for low exercise adherence, and this could help characterize and facilitate augmented promotion initiatives. The notion of personality-based exercise programs is popular in the media, but it has not undergone extensive testing at present. Given the generally small effect that personality has on exercise behavior, however, it seems likely that interventions based on these traits should constitute a small part of a larger promotion initiative.

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See also Anger and Violence in Sports; Arousal and Athletic Performance; Biofeedback; Exercise Addiction/Overactivity Disorders; Imagery and Visualization; Motivation; Psychological Aspects of Injury and Rehabilitation; Sport and Exercise Psychology

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Pharmacology and Exercise

Exercise pharmacology is a relatively new field that studies how exercise affects drugs and how drugs affect exercise. How exercise and drugs interact is very complex, and there has not been much research done to look at these interactions. How exercise affects a drug is not a required part of the U.S. Food and Drug Administration (FDA) drug approval process or the required postmarketing surveillance. Much of the information below is based on what is known about how exercise affects the physiology of the body, followed by logical deductions on how this will affect various drugs.

The Effect of Exercise on Drugs

The study of how the body processes a drug is called *pharmacokinetics*. Pharmacokinetics is divided into four different body functions: absorption, distribution, metabolism, and excretion. How each of these is affected by exercise is detailed below. These are only general concepts, and any particular drug may be affected differently.

Absorption

Absorption is how the drug gets into the body. Drugs can be absorbed in a variety of ways, including orally, by injections, transdermally, and by inhalation.

Oral Absorption

Most drugs are absorbed orally. Generally, the drug is dissolved in the stomach and then absorbed through the lining of the small intestine. Both of these can be affected by exercise. Light exercise can decrease stomach-emptying time, while strenuous exercise can increase it. So depending on the intensity of the exercise, it may take a shorter or longer time for the drug to leave the stomach, which will then affect how quickly the drug will take effect. Exercise also decreases blood flow to the gastrointestinal tract as blood is shunted to the heart, lungs, and muscles, to deliver more oxygen to those tissues that need it during exercise. This results in less drug being absorbed in the small intestine and thus could decrease the effects of the drug.

Injections

As mentioned above, during exercise, blood is shunted to the muscles to provide more oxygen to fuel the exertion. So drugs that are injected into muscle or the surrounding tissue will be absorbed much more quickly, and more of that medication may be absorbed into the bloodstream, resulting in higher blood concentrations. One of the most commonly injected medications is insulin, used in the treatment of diabetes mellitus. Patients who use insulin are advised to avoid injecting insulin into muscles that are going to be exercised shortly. For instance, if a diabetic is going to run, it is recommended that he or she inject the insulin into the abdomen instead of the thigh, as absorption of the insulin from the thigh will be greatly affected by running.

Transdermal Absorption

Some medicines are absorbed into the bloodstream through the skin. Examples include nitroglycerin patches and creams used to treat angina, nicotine patches to help quit smoking, and female hormones for birth control. Exercise also increases blood flow to the skin so that excess heat can be released, so these medications will be absorbed as much as two to three times more during exercise than at other times.

Inhaled Absorption

The most common medicines that are absorbed through inhalation are asthma medications. Exercise increases blood flow to the lungs to facilitate better oxygen delivery to tissues, so drug absorption through this pathway is also increased. This can be helpful in the patient with asthma because asthma is often worsened by exercise, so more medicine is absorbed when the need is greater.

Distribution

Distribution refers to the parts of the body and the tissues the medication is delivered to. The most important effect exercise would have on distribution is related to dehydration. If the exercising person does not adequately hydrate during and after exercise, the body may become dehydrated, which could increase the concentration of the drug, potentially causing side effects. The other manner in which distribution could be affected by exercise is its effect on protein binding. In the bloodstream, some drugs are bound to protein, making them unavailable to act on the body. Exercise increases the levels of protein in the bloodstream, so more of a drug is bound to protein, decreasing its effects.

Metabolism

Many drugs are metabolized by the liver, which inactivates the drug. Exercise decreases blood flow to the liver, so drugs that are metabolized in the liver may have an increased duration of action before they are metabolized. However, some studies have shown that regular exercise increases the efficiency of the liver in metabolizing drugs. So while exercise decreases blood flow to the liver, it seems to make it more efficient, and thus, these two effects probably cancel out each other.

Excretion

Excretion refers to how the drug is removed from the body. Most drugs are excreted through the kidneys. During exercise, blood flow to the kidneys decreases by as much as 50%, so this can result in drugs remaining in the bloodstream longer and increasing their concentrations. Some drugs are excreted by the liver into the bile and then leave the body through the stool. Regular exercise increases bile excretion, so drugs excreted through this route are eliminated more quickly. One example of this is acetaminophen.

Summary

As can be seen, the topic of how exercise affects drugs is very complex. While there are some drugs that have been extensively studied, the effect of exercise on most drugs has not been researched. With the current lack of knowledge, it is difficult to make definitive statements about how a specific drug will be affected by exercise, but a significant impact resulting in severe side effects or toxicity is possible.

The Effect of Drugs on Exercise

Many drugs have been found to have an effect on exercise. This section discusses some commonly prescribed medications as well as common over-the-counter drugs that will change the body's ability to exercise. It is recommended that if you are taking any of these medications that may be adversely affecting your ability to exercise, you should discuss it with your physician before making any changes to your treatment plan.

Beta Blockers

Beta blockers are among the most commonly prescribed medications for hypertension and other cardiovascular diseases. Apart from decreasing the blood pressure, beta blockers decrease the resting heart rate and blunt the heart's ability to increase its rate with exercise. Because of these effects on the heart, beta blockers decrease the body's ability to exercise, commonly resulting in fatigue. For this reason, beta blockers may not be the best option for patients who exercise regularly, especially if taken for hypertension.

Diuretics

Diuretics are drugs that increase the removal of water by the kidneys and are commonly prescribed for the treatment of hypertension and congestive heart failure. Since exercise can result in loss of fluid through sweat, patients who exercise while taking diuretics are at increased risk for dehydration. Patients need to assess their hydration status closely when exercising while on these medications.

Antihistamines

Antihistamines are drugs commonly used to treat seasonal allergies or upper respiratory illnesses. They can be divided into two classes or generations. First-generation antihistamines include diphenhydramine (Benadryl), chlorpheniramine (Chlor-Trimeton), and clemastine (Tavist) and are the most common antihistamines included in over-the-counter medications for allergies and colds. Second-generation antihistamines include cetirizine (Zyrtec), loratadine (Claritin), desloratidine (Clarinex), and fexofenadine (Allegra) and are newer agents that are available over the counter (cetirizine, loratidine) or by prescription only (desloratidine, fexofenadine). First-generation antihistamines have a higher incidence of side effects than second-generation antihistamines. During exercise, first-generation antihistamines can decrease the ability of the body to sweat, thus increasing the risk of hyperthermia. They also can cause drowsiness and sedation, affecting exercise performance. For this reason, second-generation antihistamines are generally preferred for athletes.

Statins

Statin drugs are the most commonly prescribed class of drugs to treat hypercholesterolemia. Most patients can take these medications without side effects. However, this class has been linked to myopathy, a disease of muscle that can result in muscle destruction in severe cases. Strenuous exercise is thought by some to increase the risk of this side effect, so it is recommended for patients taking these medications, especially older males who are deconditioned, to avoid intense weight lifting or other strenuous exercises.

Nonsteroidal Anti-Inflammatory Drugs (NSAIDs)

Nonsteroidal anti-inflammatory drugs (NSAIDs) are commonly used to treat pain and inflammation, especially for musculoskeletal injuries and muscle soreness after exercise. Over-the-counter examples include aspirin, ibuprofen, and naproxen, and there are more than 20 NSAIDs available by prescription. Some studies have shown quicker recovery from muscle soreness after exercise when on these drugs, which could enable a person to exercise more frequently. While they are commonly used, there is a growing concern that these drugs may slow the healing response, especially in fractures and cartilage injuries.

Narcotic Pain Medications

Narcotic pain medications are used to treat severe pain, often from acute injuries. Narcotics include codeine, hydrocodone, and oxycodone and are available in a number of prescription formulations. A common side effect of narcotics is sedation and drowsiness, so athletes should be cautioned against exercising and competing while under the effects of narcotics.

Muscle Relaxers

Muscle relaxers are used to decrease muscle spasms, especially spasms associated with cervical and lumbar sprains and strains. They also cause sedation and drowsiness, so exercising while on these medications should probably be avoided.

Fluoroquinolone Antibiotics

Examples of fluoroquinolones include ciprofloxacin (Cipro), levofloxacin (Levaquin), norfloxacin (Noroxin), and ofloxacin (Floxin). Fluoroquinolones are one of the most commonly prescribed classes of antibiotics due to their broad spectrum of activity against many different bacteria and the low prevalence of side effects. However, the FDA has recently added a warning concerning the risk of tendon-related side effects, including an increased risk of tendon ruptures. Because of this, many sports medicine physicians avoid using this class of medications in athletes.

Michael Stump

See also Nonsteroidal Anti-Inflammatory Drugs (NSAIDs); Performance Enhancement, Doping, Therapeutic Use Exemptions

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Physiatry and Sports Medicine

Physiatrists are physicians who are experts in the biomechanics and function of nerves, muscle, and bone. They treat injuries or illnesses that affect people's quality of performance. The goal of a physiatrist is to treat the whole person in order to restore function. Besides diagnosing and treating the condition, physiatrists work to prevent further disability. Physiatrists take a team approach with the patient and care providers to rehabilitate the patient.

A physiatrist should have completed medical school and 4 years of postdoctoral training in a physical medicine and rehabilitation (PM&R) residency. All physiatrists are trained to care for general musculoskeletal injuries. Some physicians may pursue fellowships in sports medicine, interventional spine, neuromuscular medicine, spinal cord injury, traumatic brain injury, electrodiagnostic medicine, and pediatric rehabilitation.

When seeing a patient for a sports-related injury, a physiatrist will first assess the injury using a focused and detailed history and physical exam. In some cases, further testing may be ordered or performed, including imaging studies (to visualize the structures involved) and electrodiagnostic studies (to test the muscles and nerves). The most important part of the physiatrist's treatment is to address and educate the patient about the biomechanics that may have contributed to the injury. By facilitating body awareness, the physiatrist engages patients in his or her treatment, assesses faulty habits, and prevents further injury. As head of the rehabilitation team, the physiatrist will then devise a rehabilitation program, providing direction to the physical therapists and/or occupational therapists. The physiatrist will continue to follow the patient's condition to maximize the return to the patient's pre-injury level of activity. Physiatrists also receive training in bracing and orthotics and may prescribe a device to maximize function and minimize pain.

In addition, a physiatrist is expert in treating acute pain. This may be done so that the patient can start physical therapy as soon as possible. Physiatrists are trained in many interventions, including injections of anti-inflammatory medication to relieve arthritic joints or inflamed tendons, viscosupplementation to replace the normal joint fluid, and trigger point injections to help relieve areas of focal muscle spasm. Medications may also be prescribed.

As experts in rehabilitation, physiatrists work with a wide spectrum of patients, from elite athletes to quadriplegic patients, who are unable to move on their own but would like to participate in sports. Physiatrists may develop exercise plans for athletes, overweight patients looking to get fit, elderly patients recovering from a heart attack, or patients with progressive neurological diseases. They have the expertise to prescribe exercise programs and assistive devices for athletes with new, disease-related limitations. Many physiatrists conduct research involving sports and exercise endurance, physiology, and biomechanics. They collaborate with their patients and, as needed, with their patients' families, therapists, and social workers to develop a plan to meet the patients' treatment goals. Physiatrists have a unique role in patient care; they incorporate the medical, social, emotional, and vocational effects of an injury into the treatment plan.

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See also Careers in Sports Medicine; Physical and Occupational Therapist; Principles of Rehabilitation and Physical Therapy

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Physical and Occupational Therapist

Occupational therapists (OTs) and physical therapists (PTs) are key members of the sports medicine interdisciplinary team. They assist in the prevention, evaluation, diagnosis, and treatment of sports-related injuries. OTs and PTs provide guidance for a safe and early return to play.

The American Physical Therapy Association (APTA) defines physical therapy as "a health profession whose primary purpose is the promotion of optimal human health and function through the application of scientific principles to prevent, identify, access, correct, or alleviate acute or prolonged movement dysfunction." To become a physical therapist, one must earn a master's or doctorate degree from an accredited physical therapy program. This process takes approximately 5 to 7 years. PTs work with a diverse patient population, including patients with neurological, cardiopulmonary, orthopedic, and physical developmental conditions. Physical therapists can obtain a specialist certification in sports physical therapy with formal study and clinical experience through the APTA. As of 2007, 7,573 physical therapists have been certified as clinical specialists, and 640 are certified as specialists in sports medicine.

According to the American Occupational Therapy Association, occupational therapy involves the "therapeutic use of work, self-care, and play activities to increase independent function, enhance development, and prevent disability. It may include adaptation of task or environment to achieve maximum independence and to enhance the quality of life." OTs earn a master's degree from an accredited occupational therapy program. This process takes 5 to 6 years. Occupational therapists work with a wide patient population, including those with developmental delays and neurological, cardiopulmonary, orthopedic, and psychiatric conditions. Occupational therapists who work in sports medicine are typically certified hand therapists and specialize in upper extremity conditions. To become a certified hand therapist, you must have a minimum of 5 years of clinical experience working with upper extremity injuries and must have passed a board certification exam. Certified hand therapists comprise both occupational therapists and physical therapists.

Some examples of injuries that a PT would see include anterior cruciate ligament (ACL) tear, patella dislocation, low back pain, shoulder dislocation, ankle sprain, tennis elbow, plantar fasciitis, and shin splints. Examples of injuries an OT might see include hand and wrist fractures such as scaphoid fracture, hand and wrist tendon injuries such as jersey finger or skier's thumb, and elbow and wrist nerve injuries such as cubital or radial tunnel.

PTs and OTs are key in assisting sports medicine teams' efforts to prevent sports injuries. They work with athletes to increase flexibility, strength, and endurance and teach proper body mechanics and techniques specific to the athlete's sport. Examples of this include teaching in ACL injury prevention programs that focus on learning how to jump safely; providing a program for dancers that focuses on core strengthening, posture, flexibility, and proper technique to reduce injuries such as stress fractures of the spine; or providing a stretching program for tennis players to help prevent medial epicondylitis.

Despite efforts to prevent sports injuries, athletes continue to sustain injuries. PTs and OTs evaluate injuries and use many assessment and screening tools. They assess pain with visual analog scales, soft tissue edema with circumference measurements, and flexibility using tests such as popliteal angle measurements and the Thomas test. Strength is measured by performing manual muscle tests, isometric testing, and using grip dynamometers. PTs and OTs perform provocative tests such as the Lachman test, which assesses the stability of the ACL. Hand and upper extremity OTs will use provocative tests of the hand, such as palpation, the Phalen test, and the scaphoid shift test, to assess instability and fracture healing. PTs and OTs evaluate an athlete's technique, as in throwing, running, dancing, and swinging a bat or a tennis racquet. After a thorough evaluation, the PT or OT formulates a treatment plan or may refer the athlete to a physician for further clinical testing or imaging, such as an X-ray, computed tomography (CT), or magnetic resonance imaging (MRI).

A majority of sports medicine injuries will require follow-up PT or OT care. Early controlled motion or immobilization may be required. OTs/hand therapists are skilled in fabricating splints for immobilization and protection, using proper positioning of ligaments. PTs and OTs teach an athlete how to stretch properly and how to strength train safely and effectively. They use skilled techniques such as joint distraction, joint mobilization, and soft tissue mobilization. Physical agents and modalities may be an adjunct to therapy to decrease swelling, reduce pain, relax muscles, increase blood flow, and provide biofeedback to muscles. Examples of these modalities include therapeutic ultrasound, neuromuscular electrical stimulation, iontophoresis, and kinesiotaping techniques. Therapists provide recommendations regarding braces, splints, foot orthotics, and footwear.

If surgical intervention is required, sports medicine surgeons refer patients to physical and occupational therapy postoperatively. Therapists are knowledgeable in surgical procedures and guide the athlete through the postoperative stages of rehabilitation. The therapy following surgery addresses edema control, pain, wound care, dressing changes, splinting, precautions, crutch training, range of motion, strengthening, gait training, muscle reeducation, and strengthening.

The PT and OT guide the athlete back to his or her sport as safely and quickly as possible. The therapist reevaluates the athlete's flexibility, endurance, and strength. The athlete is asked to participate in functional, sport-specific tests. The therapist uses tools such as isokinetic testing, which provides an objective measurement of muscle strength, endurance, and power. Functional tests such as the hop test and agility test may be indicated. Physical and occupational therapists also provide splints, taping, or other devices that may help the athlete return earlier to sports. These tests and recommendations provide important information for the sports medicine physician as he or she determines when an athlete can return to sports safely.

PTs and OTs are a critical part of the sports medicine team, and one can appreciate how vital their role is in the management of sports-related injuries.

Elizabeth Marie Gonski

See also Careers in Sports Medicine; Cryotherapy; Deep Heat: Ultrasound, Diathermy; Electrotherapy; Hydrotherapy and Aquatic Therapy; PRICE/MICE; Principles of Rehabilitation and Physical Therapy; Sports Massage Therapist; Superficial Heat; Therapeutic Exercise

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Physical Examination and History

Medical examinations to evaluate any health risks for people considering participation in sports are called *preparticipation examinations* (PPE). The main aim of the PPE is to establish the conditions under which people can safely participate in exercise, bearing in mind their individual medical conditions and the nature of the activities involved. An American Academy of Family Physicians (AAFP) monograph on the PPE was first published in 1992, providing guidance on the content and format of the PPE. The third edition, updated in 2005, is supported by six national medical societies: the AAFP, American Academy of Pediatrics (AAP), American College of Sports Medicine, American Medical Society for Sports Medicine (AMSSM), American Orthopaedic Society for Sports Medicine, and American Osteopathic Academy of Sports Medicine (AOASM).

The PPE is different from normal periodical health examinations and focuses on the issues likely to be encountered during exercise. Physicians vitally interested in the health care of athletes stress the importance of the PPE, which has primary and secondary goals. The primary goals are as follows:

1. To uncover relative or absolute medical contraindications to participation in particular activities: Examples include hypertrophic cardiomyopathy, aortic stenosis, hypertension, and asthma; being aware of the risk of sudden death allows the introduction of protective measures, making sports participation safer.
2. To detect the presence of physical deficiencies and/or medical conditions that predispose individuals to exercise-related disease or injury, with a view to modifying or limiting certain activities.
3. To comply with any legal or sports organization–based requirements: Health care providers should know the legal procedures of their particular countries and the sports involved.

The secondary aims of the PPE are as follows:

1. To review the general state of health of the individual and, where necessary, to introduce provisions to maintain health and safety: Sometimes the PPE is the only contact that the young athletes have with health care professionals.
2. To assess behaviors that cause health risks and evaluate suitability for undertaking exercise.
3. To identify the developmental level of young athletes whose physical development is not yet complete (e.g., the presence of epiphyseal growth plates that have not yet closed) and evaluate the effect of exercise on this development.

Types of Examination

The PPE is generally done in three types of situations: (1) office-based examinations performed by a doctor one-on-one with the athlete; (2) station-based health evaluations done by a multidisciplinary team, including physicians, sports trainers, dieticians, and physical therapists; and (3) line-up examinations. Each approach has advantages and disadvantages.

Office-based examination can be done by the athlete's personal physician. Advantages include an ongoing relationship that makes the discussion of sensitive issues easier and ready access to medical records covering previous injuries and treatment. The disadvantages are low cost-effectiveness, high cost to the athlete, and a generally low level of education about sports medicine among primary care doctors, potentially producing inconsistent advice.

Station-based PPEs can provide extensive screening, involving doctors, nurses, sports trainers, physical therapists, coaches, and/or parents who are experienced in sports medicine and covering the assessment of body composition, elasticity, muscle power, and other physical fitness parameters. They are time- and cost-effective and offer a standardized evaluation for every athlete. Other advantages include providing a database of information for research and a forum for training sports physicians and allied health professionals. However, there are usually no opportunities to discuss personal issues, sensitive medical problems, or individualized advice or to develop relationships with the athletes and, where appropriate, their parents.

Line-up PPEs are time- and cost-effective but offer no privacy and raise concerns about confidentiality. Most sports physicians would not recommend their use. Most primary care providers perform PPEs in their offices. However, it is also common for doctors to participate in school-based mass-screening examination programs. Optimum, station-based PPEs are rarely possible in this situation.

Frequency of Examination

The frequency of the PPE depends on the age of the athlete, the type of sports, the resources of any schools or organizations involved, and the requirements of the country.

The American Heart Association published a consensus proposition about cardiovascular PPE screening in 1996, recommending that this be done before beginning competitive sports in high school or college and biennially thereafter. The American Association of Pediatrics recommends a complete initial evaluation with a brief review at the beginning of each new sports season. Currently, a great many authorities recommend a PPE at the beginning of each new sports season to uncover any new problems and/or assess rehabilitation following old injuries. Other authorities suggest annual screenings.

Enough time should be set aside to diagnose new problems and assess and treat existing ones. However, this time limit for addressing problems should not be too distant from the school time or sports season, when new problems arise. Some authors recommend a PPE at least after 4 weeks and optimally 10 to 12 weeks before the sports season begins, which is enough time to assess the effectiveness of any interventions that are recommended as a result of the PPE. Others recommend PPEs 4 to 6 weeks before the season starts. Summer holidays are a convenient time for athletes attending school.

The PPE not only identifies the risk of harm but also helps individuals undertake measures to reduce this risk. It consists of a history and examination and, occasionally, investigations.

Medical History

The medical history is a very important part of the PPE because it alerts the physician to the athlete's current and past illnesses, medications, injuries, surgical interventions, and so on. A comprehensive history can define 65% to 92% of the problems that affect the athletes. The history should focus on the cardiovascular, neurologic, and musculoskeletal systems, looking for medical or orthopedic problems that could lead to life-threatening or disabling exercise-induced injury or illness. Because occult cardiac disease increases the risk of sudden death, the American Heart Association recommends asking about the following:

- Chest pain or illness with exercise
- Syncope or near syncope
- Unexplained dyspnea or exhaustion with exercise
- Heart murmurs
- Blood pressure
- A history of early and/or sudden death in the family, especially in people below 50 years of age
- Personal or family history of hypertrophic cardiomyopathy, dilated cardiomyopathy, prolonged QT syndrome, Marfan syndrome, or clinically important arrhythmias.

A thorough orthopedic history is a good screening tool, uncovering 92% of the conditions. Important points to be considered are past injuries that allow only limited participation in sports (twists, strains/sprains, dislocations, fractures, and other joint and skeletal problems) and injuries resulting in permanent functional limitation, as well as any treatments to date. It is important to check the neurologic system carefully, inquiring about injuries with loss of consciousness, hospitalization, brain surgery, and temporary paresis and/or paresthesias. Other important areas include past and current medical problems, hospitalizations, allergies, and medications. Women should be questioned about their menstrual cycles (menarche, date of last normal menstrual period, menstrual dysfunction), past pregnancies, and diet.

For all age-groups, it is important to ask about alcohol, tobacco, illicit drug use, and sexuality, and appropriate advice should be given. It is usually appropriate to make follow-up appointments to discuss any sensitive issues that arise.

Different counties may require different components in the history-taking part of the PPE. An ideal history-taking tool would be short, contain the required questions, be comprehensible to the athletes and their families, and contain adequate space to detail any positive responses. Helpful and effective screening tools for physicians have been developed by the AAFP, AAP, AMSSM, and AOASM (Forms 1 and 2 are available at http://www.aafp.org/afp/20000815/765.html). They provide guidance for the physician and the athlete. A form is filled out by the athlete before the PPE; adolescent athletes fill out the forms first, and then their parents revise them. The forms should be completed during the first assessment and updated during subsequent visits. Problem areas uncovered by the form warrant subsequent detailed physical examination.

Physical Examination

The content of the physical examination is, as with the history, primarily determined by the primary aims of the PPE: to define any medical problems that limit participation in exercise and to detect any medical conditions that would predispose an athlete to injury or disease. Therefore, the cardiopulmonary and musculoskeletal systems are key targets for the physical examination.

While physicians should examine all the systems during the physical examination, they should focus attention on any potential problems uncovered during the history. The initial physical examination should be comprehensive; subsequent regular examinations may be more restricted. Different types of exercises call for a focus on different body regions or systems.

Examination begins with measuring height, weight, visual acuity, and blood pressure. Standard height and weight charts should be used for pediatric athletes. Deviation from the norm requires further assessments. Low-weight individuals should be assessed carefully for eating disorders. Visual acuity may be checked using a Snellen chart: Individuals with visual problems are more at risk of harm from contact sports. If the blood pressure is high, the measurement should be repeated.

The cardiovascular examination should concentrate on, but should not be limited to, the following items:

- Auscultation of the precordium, with the patient supine and erect, to detect the continuous murmurs of left ventricle outlet obstruction
- Assessment of the femoral arterial pulses, to exclude coarctation of the aorta
- Looking for the features of Marfan syndrome
- Measuring the brachial blood pressure while seated
- Considering electrocardiogram (EKG), chest X-ray, echocardiogram, and/or stress echocardiogram if there are worrying features in the history or physical examination (i.e., rhythm disorders and murmurs)
- Auscultating the lungs: (If there is exercise-induced bronchospasm, the athlete should be assessed after exercise.)

During the abdominal examination, masses and organomegaly should be ruled out. Male genitourinary system examination is performed to look for cryptorchidism, testicular masses, and Tanner staging in the pediatric age-group. Female pelvic examination is not a routine part of the PPE, but if there are menstrual irregularities, the individual should be encouraged to have an examination by her own doctor.

Musculoskeletal system examination is performed to diagnose any orthopedic or rheumatologic conditions. While it is rare for musculoskeletal problems to make it impossible for an individual to participate in exercise, these are nevertheless common problems that require further evaluation. Previous injuries require repeated assessment. During the musculoskeletal examination, check for symmetry of the upper and lower extremities and trunk, cervical spine mobility, muscle strength and joint flexibility in the areas that are important for the exercise program being considered, and the curvature of the thoracic and lumbosacral spine and the range of spinal movements. Anatomical anomalies and decreased ranges of movement require further examination. Neurological examination is a part of the PPE.

Routine Screening Tests

Routine laboratory tests are not recommended for young athletes. However, abnormalities uncovered during the history or physical examination may require laboratory, radiography, or other diagnostic tests. If athletes request a simultaneous general screening examination, appropriate screening tests will be dictated by their age, sex, family history, and general health.

Cardiovascular tests are not recommended unless there are clinical indications. If there is a family history of early atherosclerotic heart disease, athletes should have a lipid profile taken. A family history of sudden cardiac death should prompt assessment for conditions such as congenital prolonged QT syndrome and Brugada syndrome. Some authors recommend pulmonary and cardiovascular screening with chest X-ray, EKG, and echocardiogram to look for anomalies that can lead to sudden death. Others claim that such screening is unnecessary unless there are worrying features in the history and physical examination.

Consent for Participation

At the end of the PPE, physicians must make a decision about participation in exercise, taking into account the type(s) of sports, findings of the history and examination, and results of any investigations. Consent for participation can be granted if the answer is "no" to all the following questions:

- Is there an increased risk of mortality or morbidity?
- Is there a risk to other athletes?
- Is further evaluation, treatment, and/or rehabilitation required?

If problems prohibit full participation, consider whether the athlete could participate in restricted activities.

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See also Preparticipation Cardiovascular Screening; Presports Physical Examination; Sudden Cardiac Death; Team Physician

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Physically and Mentally Challenged Athletes

Individuals with physical and intellectual disabilities regularly compete in sports alongside athletes with and without similar disabilities. This entry outlines the benefits of sports and exercise for individuals with disabilities and provides information on participation levels, barriers, special considerations, and program design. The discussion is intentionally broad because individuals with disabilities represent a heterogeneous population and each individual has his or her own unique needs. This entry provides general guidelines that could assist coaches, fitness instructors, health professionals, and teachers in implementing and/or supporting a program that would include individuals of all abilities. This entry also focuses on both sports *and* exercise for individuals with disabilities, with an emphasis on participation in community programs for recreation and health.

Defining Disability

The World Health Organization states that

> disabilities is an umbrella term, covering impairments, activity limitations, and participation restrictions. Impairment is a problem in body function or structure; an activity limitation is a difficulty encountered by an individual in executing a task or action; while a participation restriction is a problem experienced by an individual in involvement in life situations. Thus disability is a complex phenomenon, reflecting an interaction between features of a person's body and features of the society in which he or she lives. (http://www.who.int/topics/disabilities/en)

There is no universal agreement on the definition of the term *disability,* but the shift from a medical model of disability to the social model has been widely accepted. This means that people's physical, cognitive, or sensory limitations are no longer the center point of disability; rather, it is the interaction of their functional status with their environment. If an environment is free of physical and attitudinal barriers and offers appropriate support to accommodate people of all abilities, then a person with a disability can fully participate in all aspects of society. This includes involvement in competitive and recreational sport.

Prevalence rates of disability vary radically around the world, in part because surveys and data collection methods differ. The lack of a standard definition of disability as well as comorbidities and multiple pathologies contribute to the uncertainty of current prevalence estimates. Rates have ranged from less than 1% to 20% of a nation's population, and the United Nations estimates that disabilities are prevalent in 10% of the world's population.

Participation in Sports and Exercise

Sports for People With Disabilities

Individuals with physical and intellectual disabilities have excelled in competitive and recreational sports for many years. An athlete with a disability may elect to engage in inclusive sports alongside nondisabled individuals (i.e., regular sports) or in adapted sports alongside other individuals with similar disabilities (i.e., disability sports). Opportunities for athletes with disabilities to compete at an elite level and to achieve athletic excellence are often within disability sports, such as the Paralympics. However, athletes with disabilities have also competed at the highest level of regular sports. Jim Abbot (Major League Baseball pitcher from 1989 to 1998) and Casey Martin (former golfer on the PGA tour and member of the 1994 National Collegiate Athletic Association Championship golf team) are just two examples of high-performance athletes with disabilities.

There are a number of international organizations that govern sports programming for athletes with disabilities, including Cerebral Palsy–International Sports and Recreation Association, International Blind Sports Association, International Committee on Silent Sports, and Stoke Mandeville Wheelchair Sports Federation. The International Paralympic Committee is the governing body of the Paralympic Movement, which was initiated by Sir Ludwig Guttman. Guttman was the first to recognize the therapeutic benefit of competitive sport in the lives of people with physical disabilities, and he organized the Stoke Mandeville Games for World War II veterans with a spinal cord injury in 1948. The first organized Olympic-style games for individuals with disabilities followed in Rome in 1960, where 400 athletes competed. A total of 3,951 athletes from 146 countries competed in the 2008 Paralympic Games in Beijing, a notable increase from 3,806 athletes in Athens just 4 years earlier. The Paralympics are elite sports events for athletes from six different disability groups: amputee, cerebral palsy, visual impairment, spinal cord injuries, intellectual disability, and les autres ("the others"). There are 27 summer and winter sports in the Paralympics, some of which are sports designed specifically for athletes with disabilities, such as goalball, wheelchair basketball, wheelchair rugby, ice sledge hockey, and sitting volleyball. Each sport has a classification system, and athletes are allotted a class defined by the degree of function presented by their disability.

Special Olympics is an international organization that offers sports training and competition to

2.5 million athletes with intellectual disabilities around the world. The movement was initiated by Eunice Kennedy Shriver, who believed that people with intellectual disabilities should be afforded the same opportunities as others and that sports could be an avenue for self-actualization. In 1968, the first International Special Olympics Games took place in Chicago, with 1,000 athletes from the United States and Canada. According to its Mission Statement, Special Olympics aims to give children and adults with intellectual disabilities the opportunity to "develop physical fitness, demonstrate courage, experience joy and participate in a sharing of gifts, skills and friendship." There are training and competition opportunities in 30 Olympic-type sports, and athletes participate in local, regional, national, and international events. Athletes are classified according to age, gender, and ability and compete against others of similar ability in equitable divisions. The 2007 Special Olympics World Summer Games were held in Shanghai, where approximately 7,500 athletes representing 165 countries competed in 25 sports. The most recent Winter Games were held in Nagano, where more than 1,800 athletes from 80 countries competed in 7 sports.

Exercise/Physical Activity for People With Disabilities

As is true with the general population, most individuals with physical and intellectual disabilities do not possess the skills required to compete at an elite level. However, all are able to benefit from participation in exercise and sports programs. Recreational opportunities including intramural programs, community sports teams, fitness classes, and physical education can generally accommodate people of all abilities and should be emphasized in health promotion efforts. Research indicates that children and adults with disabilities do not engage in adequate physical activity and spend considerable time in sedentary pursuits such as watching television. In the United States, for example, 37.7% of adults with a disability reported meeting the recommended levels of physical activity in 2005 versus 49.4% of adults without a disability. The prevalence of persons with a disability who met the recommendations ranged from 23.2% to 53.3%. Significantly more adults with a disability (25.6%) also reported being physically inactive during a typical week than nondisabled adults (12.8%). Low levels of physical activity contribute to the higher incidence of overweight and obesity, coronary heart disease, and poor fitness levels observed in people with physical and intellectual disabilities.

Benefits of Involvement in Sports and Exercise

The benefits of regular exercise for health and functioning in general populations are well established and include reduced risk of coronary heart disease, hypertension, obesity, osteoporosis, and different types of cancer. Benefits also include increased emotional well-being, self-confidence, body awareness, and reduced levels of stress and depression. Participation in sports offers additional benefits such as developing sportsmanship, as well as opportunities for team building, competition, and socialization. Individuals with physical and intellectual disabilities derive these same benefits from exercise and sports, and their participation may be even more important. Regular exercise reduces the risk for some secondary disabling conditions, such as obesity, joint contractures, and diabetes, which could exacerbate the problems of a primary disability. Furthermore, regular exercise improves function, which can increase independence in activities of daily living, recreational pursuits, and professional tasks and reduce the need for assistance. Sports provide children and adults with disabilities an outlet for "normalization" and are an excellent means to facilitate inclusion. Sports programs for individuals with disabilities can be for the purpose of education, leisure, health and wellness, elite competition, and/or therapy, but an important objective is to maximize self-actualization.

Correlates of Sports and Exercise

The factors associated with exercise participation by people without disabilities have been studied extensively and are generally consistent. However, little is known about why people with disabilities do, or do not, engage in regular exercise and sports. There is a need to better understand the factors that support and impede the ability of people with disabilities to exercise and to participate in sports.

Barriers

The barriers to exercise participation faced by people with physical disabilities include a variety of personal and environmental variables. Cost of programs and services, no means of transportation, no knowledge of where to exercise, and no knowledge of how to exercise are frequently reported barriers to participation among people with physical disabilities. Low exercise self-efficacy, lack of time, low energy/motivation, and concerns associated with health are also common. The barriers encountered by people with physical disabilities that are unique and do not typically apply to the general population include inaccessible exercise facilities, lack of adapted equipment, untrained coaches/instructors, and overprotection by care providers and health professionals.

Individuals with intellectual disabilities have reported that the cost of programs, the weather, time limitations, and limited transportation restrict opportunities to participate in exercise and sports. Lack of energy, feeling that exercise is boring, concerns about health, and having no one to teach them to exercise are also barriers faced by people with intellectual disabilities. Unlike the general population, inaccessible facilities, lack of guidance, fear of injury, and negative influences by care providers are obstacles reported by this group.

Facilitators

Information about the factors that promote exercise participation among individuals with disabilities is scarce. Most of the work in this area has focused on athletes and their motivations for competing in sports. For example, athletes with intellectual disabilities who participate in Special Olympics training and competition report being motivated by winning ribbons, having fun, and making new friends. Adults with physical disabilities have noted that an accessible built environment (e.g., parking spaces, ramps, automatic doors), availability of adapted equipment, trained and motivated coaches/instructors, and opportunities to try programs to determine their comfort level would facilitate engagement in exercise and sports.

Special Considerations for Participation

Individuals with disabilities respond to exercise and sports training with improved performance and capacity. They are equally able to adapt to increased levels of intensity through enhanced fitness and progressive development of motor skills. That being said, it may be necessary to modify the components of a sport or exercise to accommodate functional limitations such as low strength, balance, speed, endurance, or range of motion. The cognitive, behavioral, motor, and/or communication deficits associated specifically with intellectual disabilities may also require that an activity be adapted so that an individual can be successful and a training effect achieved. A few considerations for coaches and fitness professionals to promote safe participation of people with disabilities in sports and exercise are highlighted below. These examples are not meant to be exhaustive but only provide insight into some exercise-related conditions. Practitioners are encouraged to get to know each person individually and to understand his or her strengths and limitations in order to meet his or her unique needs.

Individuals With Physical Disabilities

Individuals with spinal cord injuries often have impairment in the autonomic and sensory nervous systems. As a result, normal thermoregulatory function is altered, leading to problems with hyper- and hypothermia. This is particularly true for individuals with injuries above T6 (i.e., the sixth thoracic segment). Hypotension (low blood pressure) may also be a consequence of disruption in the sympathetic nervous system and results from blood pooling in the legs and reduced venous return. Autonomic dysreflexia, a dangerously rapid increase in heart rate and blood pressure with associated anxiety, headache, and profuse sweating, is also a risk for individuals with spinal cord injuries above T6. This can arise from bowel or bladder distension, skin irritation, urinary tract infection, and other pain stimuli. Some of these conditions are seen in people with spina bifida and cerebral palsy, who can also experience seizures, spasticity, contractures, hydrocephalus (spina bifida), and obesity. Taking care to include appropriate warm-up and cooldown, avoiding exercise in extreme temperatures, encouraging proper clothing to retain or dissipate heat, and exercising in a reclined position (e.g., the recumbent bicycle) are appropriate precautions for some of these conditions.

The incidence of injury in wheelchair athletes is low, and injuries are generally minor. Abrasions, skin lacerations, and soft tissue contusions make up the majority of injuries, although fractures and dislocations in the upper body are also reported. Overuse injuries such as tendinitis in the shoulder, wrist, and hands may occur in wheelchair athletes and should be taken into account by coaches/instructors.

Individuals With Intellectual Disabilities

There is no evidence that athletes with intellectual disabilities are at greater risk for injury during sports than those without disabilities. As long as coaches/instructors offer precise instruction, planned opportunities for practice, and additional supervision as needed, children and adults with intellectual disabilities can safely engage in exercise and sports. However, individuals with intellectual disabilities may have limited attention, reduced ability to retain information, impulsivity, and limited motivation, which will have to be considered in programming to ensure that athletes understand safe practices. Overweight and obesity, diabetes, seizure disorders, and vision problems also need to be managed in order to reduce the risk of sports-related injuries.

Down syndrome is a genetic condition associated with intellectual disabilities that requires special consideration for exercise and sports. There are several medical problems commonly associated with Down syndrome that may warrant medical clearance prior to participation, as well as careful programming. Specifically, muscle hypotonia (low tone) and associated hypermobility of the joints often cause orthopedic impairments such as atlantoaxial instability, lordosis, and dislocation of the joints. Individuals with Down syndrome also may have poor vision and hearing and impaired balance, which must be taken into account. Approximately 40% of individuals with Down syndrome develop congenital heart disease. Heart rate monitoring to estimate exercise intensity in people with Down syndrome may be misleading since resting heart rate is unusually low and heart rate often rises quickly at the onset of exercise.

Program Design and Organization

It is important to emphasize that people with disabilities can safely participate in vigorous exercise and sports. It may be necessary to adapt an activity to accommodate a person's functional limitations, but this can easily be accomplished through creativity and simple problem solving. Variations to rules, equipment, playing area, scoring, or organization, for example, can level the playing field for an individual with a disability without fundamentally altering the competitive nature of an activity. The steps involved in planning, implementing, and sustaining community sports programs for children and adults with disabilities are similar to those for general programs, although there are some additional factors that warrant consideration. In particular, many of the barriers to participation can be eliminated with good decision making at each step.

An important consideration for sports participation among individuals with disabilities is whether they will compete in regular sports or disability sports. The inclusion of people with disabilities in community sports programs (i.e., regular sports) should be a priority since the benefits of inclusion are clear. That being said, athletes with disabilities should have a continuum of opportunities available to them and should exercise their right to choose the environment that allows for optimal performance. An awareness of policies and legislation that promote inclusion and prevent discrimination of people with disabilities is important in community sports programming. For example, the Americans with Disabilities Act and the Canadian Charter of Rights and Freedoms have implications that encourage participation by individuals of all abilities and restrict prejudice. Some key components of community sports programs (not elite sports) for athletes with disabilities that can be useful either for inclusive opportunities or for disability sports are outlined below.

Program Planning

Accessibility of the Environment. The facility selected for a sports program should be physically accessible (e.g., ramps, automatic doors), which also includes availability of adapted equipment as well as access to transportation (accessible parking spots and/or public transportation).

Knowledge of the Athlete. Getting to know the individual athlete is critical since functional level varies significantly even within the same diagnosis. Understanding an athlete's strengths, limitations, previous experience, and motivation is a good place to start.

Coach/Instructor Training. Personnel should be educated about disabilities as well as inclusion strategies, activity/sport modifications, and safety procedures. This training can be provided by people with varied expertise, including athletes with disabilities, adapted physical activity specialists, families, physicians, and physical therapists.

Preparticipation Screening. Athletes with disabilities should be encouraged to undergo a general medical examination prior to participation in vigorous exercise or sports. This screening will help ensure that athletes are not at risk and may also reduce potential overprotection by families and coaches. Consent and/or waiver forms may also be important, with adjustments made to ensure understanding by athletes with intellectual disabilities.

Establish Trust. For full participation, it is important that trust be established between an athlete and a coach/instructor. Trust can be achieved in several ways, including providing opportunities to observe an activity prior to participation, creating a welcoming and nonthreatening environment, and giving a person control over his or her own participation through offering choices (e.g., on type of activity, the nature of modification to an activity, the extent and type of assistance needed, and equipment).

Program Implementation

Modify Sports. Be prepared to adapt the elements of a sport in order to promote success. Elements that can be easily modified include equipment, playing area, rules, players and positions, game speed, scoring, and organization. When including athletes with disabilities in regular sports, the aim is not to give them an unfair advantage but to level the playing field. One of the best examples of accommodating people of all abilities in sports is the handicap in golf.

Support. Participation in a sports program often partly depends on social support from peers, families, and/or care providers; physical support in the form of adapted equipment and accessible facilities; and instructional support from trained professionals. Providing the appropriate type and amount of support can improve self-efficacy, which is directly related to participation.

Health Limitations. Ensure that coaches/instructors are educated about the health limitations of athletes and any activities that are contraindicative. Coaches should also be trained on general safety procedures.

Program Sustainability

Evaluation. Ongoing evaluation of program priorities, skill development, and fitness is important to ensure that goals are being met. There are valid test batteries to objectively measure health-related fitness in athletes with physical and intellectual disabilities. The biomechanics of sports performance can also be examined, although this may be appropriate for high-performance athletes, where precise form is critical.

Independence. Independent participation in sports and exercise over the life span is generally the goal of community programs. It is important to involve these athletes in decisions about their participation and to teach them mastery of the functional skills that will allow for their inclusion in community-based and home-based activities with family and friends.

Continued Training. Ongoing training of coaches/instructors is important to ensure that they have up-to-date information on instructional strategies, activity/sport modification techniques, health issues, and assessment methods.

Conclusion

Participation in exercise and sports is highly beneficial for individuals with disabilities and should be encouraged. People with disabilities may face additional barriers to participation in exercise and sports because of limitations in physical, cognitive, and/or behavioral functioning, but the impact of barriers can be easily mitigated through good program design. As long as coaches/instructors, administrators, families, and health professionals are well-informed and are prepared to meet the unique needs of people with disabilities, their successful inclusion in exercise and sports programs can be realized.

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See also Medical Management of an Athletic Event; Physical Examination and History

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International Committee of Sport for the Deaf: http://www.ciss.org

International Federation for Sport for Individuals with an Intellectual Disability: http://www.inas-fid.org

International Federation of Adapted Physical Activity: http://www.ifapa.biz

International Paralympic Committee: http://www.paralympic.org

International Wheelchair & Amputee Sports Federation: http://www.iwasf.com

National Center on Physical Activity and Disability: http://www.ncpad.org

National Consortium for Physical Education and Recreation for Individuals with Disabilities: http://www.ncperid.org

Special Olympics: http://www.specialolympics.org

Physiological Effects of Exercise on Cardiopulmonary System

In exercise physiology, it is a long-held belief that cardiopulmonary fitness is the foundation of an individual's exercise capacity. Indeed, improved fitness and performance with training are in part the product of an increased capacity to supply exercising muscle with oxygen and nutrients owing to adaptations of the cardiorespiratory system. However, other significant changes in exercising muscle can result in a reduction of required cardiorespiratory effort at a given level of exercise. These adaptations are discussed in the following sections of this entry.

Cardiovascular Effects

At the onset of exercise, heart rate and stroke volume both increase, resulting in an increase in cardiac output (the amount of blood pumped through the heart in 1 minute, usually expressed in units of liters [L] per minute) and increased systemic blood supply. Over time, the body accommodates to the stress of chronic exercise by improving stroke volume (the volume of blood pumped with each contraction of the heart), which translates into improved cardiac output. Several factors combine to produce this increased stroke volume.

1. *Lower resting heart rate as well lower heart rate at a given exercise workload:* This allows increased time for the heart to fill with blood, thus increasing the amount of blood that can be pumped back out of the heart. For endurance athletes, the heart rate is often bradycardic, or less than the 50 to 55 beats/minute (bpm) considered the lower limit of "normal." The mechanism of the observed heart rate reduction appears to be reduced sympathoadrenal system activation as well as a decline in the withdrawal of vagal nerve activity during the same level of exercise in the trained versus untrained subject. The mechanistic pathway for these changes in neural stimulation remains unclear.
2. *Increased blood volume:* Blood volume in a trained individual is about 15% higher than in an untrained individual. Interestingly, this adaptation occurs very rapidly, resulting in improved exercise capacity after only a week of training. Unfortunately, it also disappears quickly, after only days of inactivity.
3. *Cardiovascular hypertrophy:* Hypertrophy is the increase in *size* of the heart muscle fibers, not an increase in the *number* of fibers. This change is evident on electrocardiogram (EKG) as well as imaging (chest X-ray, echocardiography, etc.). With exercise, hypertrophy is eccentric. This means that the volume of the ventricle increases substantially, resulting in an increase in the volume of the lumen of the chambers of the heart, while the increase in the thickness of the wall of the heart chambers is relatively minor. Hypertrophy is most evident in the left ventricle. The consequence of a larger pump is the ability to pump more blood. The eccentric hypertrophy that occurs with chronic exercise is in contrast to the concentric hypertrophy seen when the heart does more work in the setting of systemic hypertension. In hypertension, although the heart works harder, the lumen does not increase in size and the heart rate does not drop.
4. *Of note, when the heart hypertrophies, the number of capillaries and mitochondria in the heart muscle increases.* However, the *density* of the mitochondria and capillaries in the heart remains unchanged. This is in contrast to the skeletal muscle adaptations in which the density of both capillaries and mitochondria is increased. There is also no change in an individual's maximal heart rate with training. In fact, it tends to decrease slightly.

The net effect of these changes is a reduction in cardiac work over time. During exercise, clearly the heart is working harder than at rest; however, this increased work is relatively short term. For example, let's assume that an individual's untrained pre-exercise resting heart rate is 70 bpm. This individual then begins a fitness program and exercises daily with a heart rate of 140 (roughly 70% of the maximum heart rate for a 30-year-old) for 1 hour, and with training, the individual's baseline heart rate drops to 55 bpm. Over the course of a day, this will reduce the number of times the trained heart beats by 16,500 beats (see the calculations below). Thus, over time, the trained heart will work much less than the sedentary heart.

Pulmonary Effects

Respiratory output increases with exercise due to increased tidal volume and increased respiratory rate. There is also recruitment of areas of lung that are underperfused and/or underventilated at rest. These changes combine to allow the greater volume of blood moving through the lungs to continue to undergo efficient gas exchange.

Most sources suggest that there is no fundamental change in pulmonary function following a period of fitness training. For example, total lung capacity, FEV_1 (forced expiratory volume in the first second after full inspiration), and tidal volume all remain unchanged despite improved fitness. It is notable, however, that respiratory muscles undergo significant fatigue during both brief intense exercise and prolonged endurance events. While general exercise training improves respiratory muscle strength, specific focused strength training of the respiratory muscles with a respiratory trainer results in significant further gains in respiratory muscle strength. This in turn is associated with reduced dyspnea (the perception of shortness of breath) and has been linked with improved performance, even in highly trained athletes. Although at the end of the exercise most athletes have a breathing reserve by physiological measurements, these measurements do not capture the impaired ability to move air in and out of the lung that develops with respiratory muscle fatigue, and thus respiratory limitations likely remain an underappreciated cause of reduced exercise performance.

Peripheral Adaptations

As mentioned above, some of the apparent improvement in cardiopulmonary capacity is not a result of changes *within* the heart and lungs but instead is the consequence of peripheral, systemic adaptations that allow for more efficient supply and utilization of oxygen and nutrients. Single-leg training studies are very interesting in this regard. There are numerous studies in which fitness is determined in each leg pretraining using objective parameters such as anaerobic threshold, $\dot{V}O_2max$ (peak oxygen uptake), or heart rate at a given work rate as well as metabolic data and even muscle biopsy evaluation. Then a single leg is trained, usually through unilateral cycling, and postexercise parameters are compared. These data suggest that *some* but *not all* of the training effects seen in the trained leg are "transferred" and also seen in the untrained leg. There are several noncardiac systemic explanations for this transference, including the following:

1. *Increased blood volume:* As noted above, increased blood volume is an important factor in increasing stroke volume.
2. *Increased red blood cells:* The increase in red cells does not quite keep pace with the increase in blood volume; consequently, hematocrit (the volume of red cells per volume of whole blood) will be slightly reduced with training.

A component of exercise adaptation also occurs at the level of exercising muscle and is unique to the muscle trained. With training, peripheral changes include the following:

1. Increased numbers of mitochondria in the exercising muscle
2. Increased size of mitochondria in the exercising muscle
3. Formation of new capillaries within muscle (more and larger mitochondria coupled with increased capillary density, resulting in less distance for diffusion of oxygen and nutrients into the exercising muscle)
4. Increase in anaerobic work capacity by increasing the enzymes of anabolic metabolism
5. Increased ability to metabolize fatty acids for energy, which results in sparing of glycogen stores
6. Increased muscle glycogen stores
7. Enhanced local vascular control, allowing for increased blood supply to the exercising muscle
8. Reduced lactic acid production for a given level of exercise and tolerance for higher blood lactate level at the end of exercise

The net effect of these noncardiac adaptations is to spare glucose/glycogen through increased fatty acid utilization and improved anaerobic metabolic capacity, as well as to enhance oxygen delivery to and uptake by the exercising muscle. By maximizing the metabolism of alternate energy sources, aerobic metabolism is spared, and both the anaerobic threshold and the maximal oxygen uptake are enhanced. This reduces the cardiopulmonary work required to maintain a given level of exercise in the trained individual.

The calculation is as follows:

Untrained heartbeats = 70 bpm × 24 hours/day × 60 minutes/hour = 100,800 beats/day

Trained heartbeats = 55 bpm × 23 hours/day × 60 minutes/hour + 140 bpm × 1 hour × 60 minutes/hour = 84,300 beats/day

Untrained heartbeats – Trained heartbeats = 100,800 – 84,300 = 16,500 beats/day.

Clearly, this calculation is just an estimate for the purpose of illustration, since heart rate is not a constant but vacillates throughout the day in response to various stimuli. However, given that the trained heart rate will not climb as high with activities of daily living, this calculation likely underestimates the overall reduction in daily heartbeats.

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See also Cardiovascular and Respiratory Anatomy and Physiology: Responses to Exercise

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Piriformis Syndrome

Piriformis syndrome is one of the many causes of leg and buttock pain. In piriformis syndrome, the symptoms result from irritation of the sciatic nerve as it passes over, under, or through the piriformis muscle. Pressure on the nerve can lead to pain in the low back, buttock, groin, or posterior thigh, and it can be a cause of *sciatica,* with pain, tingling, or numbness along the course of the sciatic nerve. Other nerves and structures in the area may also be impinged (compressed), leading to similar symptoms.

Anatomy

The piriformis is a triangle-shaped gluteal (buttock) muscle. The base of the triangle attaches to the tail bone (sacrum). At the opposite end, the muscle attaches to the side of the upper thighbone (femur). The muscle also passes through an area of the pelvic bone called the greater sciatic foramen. The piriformis muscle is important in turning the hip out and moving the leg away from the center of the body.

The sciatic nerve is a very large nerve, important for both movement and sensation. The sciatic nerve supplies much of the skin of the leg, as well as the muscles of the back of the thigh, the leg, and the foot. It is formed from branches of the lumbar and sacral nerve roots (L4, L5, S1, S2, and S3). The nerve travels from the lower back, out of the pelvis, into the buttock, and down the back of the thigh, where it divides at the knee into the tibial and common peroneal nerves.

Because of the close proximity of the piriformis muscle and sciatic nerve, irritation and pain can develop. In some individuals, the exact location of the sciatic nerve and the structure of the piriformis muscle increase the risk of piriformis syndrome, and activities that require repeated hip motion also increase the risk. In up to 15% of cases, the sciatic nerve travels through the piriformis muscle.

Causes

Piriformis syndrome is due to entrapment and irritation of the sciatic nerve. Depending on the individual anatomy, the sciatic nerve can be compressed as it passes between the piriformis muscle and the bone of the sciatic notch, or through the muscle itself. Irritation of the nerve is more likely to occur if there is an abnormality of the piriformis, such as hypertrophy (enlargement of the muscle), inflammation, scarring, or spasm. These abnormalities can result from overuse, trauma to the area, or excessive pressure (e.g., prolonged sitting on a large wallet, or constriction by a tight, low-fitting waistband). In athletes, piriformis syndrome can also be seen following activities that cause repetitive hip rotation and extension, such as running and climbing.

Symptoms

Piriformis syndrome most commonly leads to dull aching pain in the buttock with or without radiation to the back of the thigh, knee, and calf. Numbness is rare, but tingling has been described in all five toes rather than along the path of an individual nerve. The symptoms tend to worsen with prolonged sitting or lying on the back and improve with standing and walking. Walking upstairs or uphill can be particularly painful. Activities that stretch the piriformis, such as rotating the hip and moving the upper leg, can also make the symptoms worse. Both bending and extending the hip may increase the symptoms. Also, because of the position of the piriformis close to the pelvic wall, some patients may develop pelvic pain.

Diagnosis

On physical exam, patients often have tenderness when pressure is placed on the piriformis muscle, either in the belly of the muscle or at the attachment to bone. Patients may also have tenderness to palpation of the sciatic notch and at the greater trochanter of the femur, where the muscle attaches.

A positive piriformis sign has been described in which the patient tries to avoid discomfort by keeping the leg in a slightly raised and externally rotated position when lying on the back. Other clinical tests include the Freiberg sign, which involves reproduction of the pain with passive internal rotation of the hip with the leg in an extended position, and the Pace sign, which is pain with resisted abduction and external rotation of the hip in a flexed position.

Gluteal muscle wasting (atrophy) may also be seen with long-standing nerve entrapment, especially of the peritoneal branch of the sciatic nerve.

Because the symptoms of piriformis syndrome overlap with those of many other conditions, it may be difficult to make the diagnosis. Other, more common causes of buttock pain and leg pain—such as muscle strain, sacroiliac joint irritation, and hip pathology—as well as other causes of sciatica—such as disk pathology and spinal stenosis—must be ruled out. Patients with lumbosacral radiculopathy—pain that radiates into the buttock and leg due to problems at the spine—often have pain with a straight leg raise test, whereas in piriformis syndrome, this test is typically negative. In addition, if tingling into the toes is noted with piriformis syndrome, it tends to be in all five toes rather than along the course of any one particular nerve.

Imaging studies can be useful in making the diagnosis of piriformis syndrome. Plain X-rays are typically normal. Magnetic resonance imaging (MRI) can be used to rule out other possible causes of the symptoms and can show anatomical variation or changes in the piriformis muscle that increase the risk of piriformis syndrome. Magnetic resonance neurography, which can be used to obtain images of nerves, can demonstrate swelling or other changes around the sciatic nerve to support the diagnosis. Electromyography, which records the electrical activity of muscles, may be helpful, but a negative test does not rule out the diagnosis.

Treatment

Many cases of piriformis syndrome can be successfully treated with conservative measures, which include rest from those activities that exacerbate the symptoms, oral anti-inflammatories, muscle relaxants, and physical therapy for gradual piriformis stretching. Strengthening of the piriformis and other gluteal muscles can also be beneficial. Additional treatment with ultrasound, electrical stimulation, heat, and ice has also been used with success.

If symptoms persist, trigger point injections or steroid injections, generally performed with imaging guidance, may provide relief. Use of Botox (botulinum toxin A) has also been described for treating persistent piriformis syndrome. Acupuncture can help reduce symptoms in some patients. These act to reduce pain, swelling, and/or spasm in the area of nerve compression.

If nonoperative treatment fails, surgical exploration and decompression of the nerve can address the problem. Several surgical options are available, including resection of portions of the piriformis muscle, release of muscular bands or scar tissue, and sciatic neuroplasty (surgical repair of the nerve).

Cynthia J. Stein

See also Hip, Pelvis, and Groin Injuries; Hip, Pelvis, and Groin Injuries, Surgery for

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Plantar Fasciitis and Heel Spurs

Plantar fasciitis is an injury to the plantar fascia (the fibrous membrane on the bottom of the foot) that causes heel pain. It is the most common cause of heel pain in adults. The pain is usually at its worst when taking the first few steps in the morning or after prolonged periods of activity. Plantar fasciitis is sometimes referred to as having a heel spur (deposit of bone off the calcaneus). A heel spur is a deposit of calcium in the plantar fascia that can be seen on radiographs. The presence of a heel spur does not have diagnostic value, as there is no correlation between a heel spur and heel pain. Plantar fasciitis is commonly seen in middle-aged women, young male runners, and military personnel.

Anatomy

The plantar fascia is a sheetlike membrane that helps form the arch of the foot. It originates at the medial tubercle of the calcaneus (heel bone) and forms the longitudinal arch of the foot, before attaching to the plantar aspect of the metatarsals (toes). It functions to support the arch of the foot and acts as a shock absorber during running and walking.

Causes

When the plantar fascia is overstressed, microtears can develop. Plantar fasciitis occurs when microtear formation exceeds the body's ability to repair the damage. These microtears cause a degradation of the collagen structure of the plantar fascia. The plantar fascia is put under stress and stretched with every step, therefore making it difficult for the body to repair the tear before the injury recurs. Many who suffer from plantar fasciitis do not have any evidence of bony spurs on radiographs; however, in some people, a heel spur forms as a reaction to the inflammation. The spur is not the source of the pain felt in plantar fasciitis. In fact, 15% to 25% of the population has an asymptomatic heel spur (Figure 1).

Commonly, plantar fasciitis is seen, as noted earlier, in middle-aged women, young male runners, and military personnel, but can it develop in anyone, especially those who spend a lot of time on their feet, walking on hard surfaces. Risk factors for developing plantar fasciitis include obesity, overtraining, a tight Achilles tendon, wearing shoes that lack support, overpronating when walking, pes planus (flat feet), pes cavus (high arches), ankylosing spondylitis, psoriatic arthritis, or Reiter syndrome.

Symptoms

Plantar fasciitis causes heel pain on the bottom of the foot while standing, walking, or running. Many will report having their worst pain with their first steps out of bed in the morning. The pain is usually severe at the beginning of activity but decreases after warming up. The pain then returns with prolonged activity or standing, and one may experience a throbbing or burning pain for a period of time immediately after activity has ended. Plantar fasciitis typically does not cause pain at rest but can be painful if someone applies pressure or presses firmly on the heel.

Diagnosis

History and physical exam are the best tools to diagnose plantar fasciitis. On examination, the area of maximal tenderness is usually the anterior-medial portion of the calcaneus (heel bone). A tight Achilles tendon, pes cavus, or pes planus are also diagnostic clues. Nocturnal pain is generally not a symptom of plantar fasciitis and should prompt further investigation as it could be a sign of something more serious, such as infection or a tumor. Radiographs generally are not necessary unless there is a concerning symptom from the history, such as night pain.

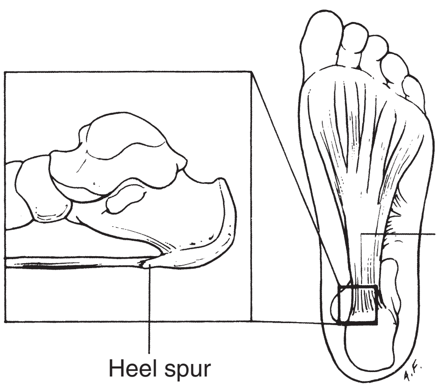

Figure 1 Plantar Fasciitis

Note: Persistent inflammation increases the possibility that a bone spur will develop where the plantar fascia attaches to the calcaneus.

Treatment

In general, plantar fasciitis improves without surgical intervention. Most see resolution of their symptoms in 6 to 8 weeks; however, plantar fasciitis can linger for up to 6 to 18 months or longer. It is especially difficult to cure those who are unable or unwilling to take time off to rest. Treatment started within the first 6 weeks from the onset of symptoms will hasten recovery.

The majority diagnosed with plantar fasciitis will find relief from very basic treatments, including rest, appropriate shoes, avoiding barefoot walking, ice application, nonsteroidal anti-inflammatory drugs (NSAIDs), and stretching. Stopping all activities that involve impact (or cause pain) is sometimes difficult to enforce in athletic patients. Not listening to this recommendation will slow recovery. Decreasing the amount of activity (i.e., the number of miles run per day) to allow symptoms to resolve and then increasing by approximately 10% per week will help avoid re-aggravating the injury once healed.

Proper support for the foot is very important, and shoes with proper fit and an adequate amount of heel cushioning should be worn at all times. Avoid wearing sandals or other shoes where the foot is not adequately supported. For serious athletes, it is recommended to get new shoes every 3 months or 500 miles (mi; 1 mi = 1.61 kilometers). Orthotics can be used for additional cushioning and support. Prefabricated orthotics are as effective as custom-made orthotics and are much cheaper. Three-quarter length or full-length orthotics are more effective than heel cups in treating plantar fasciitis.

Applying ice to the heel at the end of a long day or after exercise can be helpful for pain relief. Place the heel of the foot in an ice bath for 10 to 15 minutes or on a bag of ice for 20 minutes, or roll the heel over a frozen water bottle for 10 to 15 minutes. It is recommended to use ice two to three times per day. NSAIDs can be used acutely to help relieve pain. There is an associated risk of gastrointestinal bleeding or renal damage with chronic use of NSAIDs; thus, this class of medications is not an ideal long-term solution.

Poor flexibility in the Achilles, gastrocnemius (calf), and foot muscles can contribute to plantar fasciitis. Performing stretching exercises can help correct this problem. Stretching the calf and Achilles (by leaning against a wall or using a step) and pulling the toes back toward the shin until a stretch is felt in the plantar fascia are two of the more common stretches prescribed. Stretching before getting out of bed in the morning can help decrease the pain felt with the first steps each day.

Night splints are traditionally reserved for those who fail to obtain relief from conservative treatments. Using them involves placing the foot in a flexed position overnight by wearing a splint or a brace, in the hope that the microtears will heal at their maximum length instead of being restretched (and retorn) each morning. The disadvantages of night splints include discomfort and interference with sleep.

Injection of steroids into the heel can be done to reduce inflammation and has been shown to provide some relief. It is reserved for those who fail conservative treatments, because there are associated risks with this procedure, it can be very painful, and the pain relief may only last 4 weeks. Complications of steroid injection include fat pad atrophy, osteomyelitis (infection of the bone), nerve damage, and rupture of the plantar fascia. Some physicians will use ultrasound guidance to help reduce the risk of these complications. Giving multiple injections increases the risk of these side effects.

Extracorporeal shock wave therapy (ESWT) is generally reserved for cases of plantar fasciitis that have failed other treatment options. ESWT is one of the final treatment options before having to resort to surgery. ESWT uses a probe to focus high-energy shock waves at the area of pain. The shock waves have approximately 1,000 times the potency of an ultrasound wave. The treatment is very painful; however, it has been shown to have good long-term results in some studies.

Surgical intervention is only recommended when symptoms are not relieved after 12 months or more of treatment. A plantar fasciotomy or release of the plantar fascia can be performed through an incision or with the help of an arthroscopic camera. Up to 30% of people who undergo surgery will still have pain or activity restrictions after the surgery. Generally, the time taken for return to normal activity after the surgery is approximately 4 to 8 months. Risks include arch flattening and the general risks of surgery (infection, death).

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See also Athletic Shoe Selection; Foot Injuries; Running Injuries; Stretching and Warming Up

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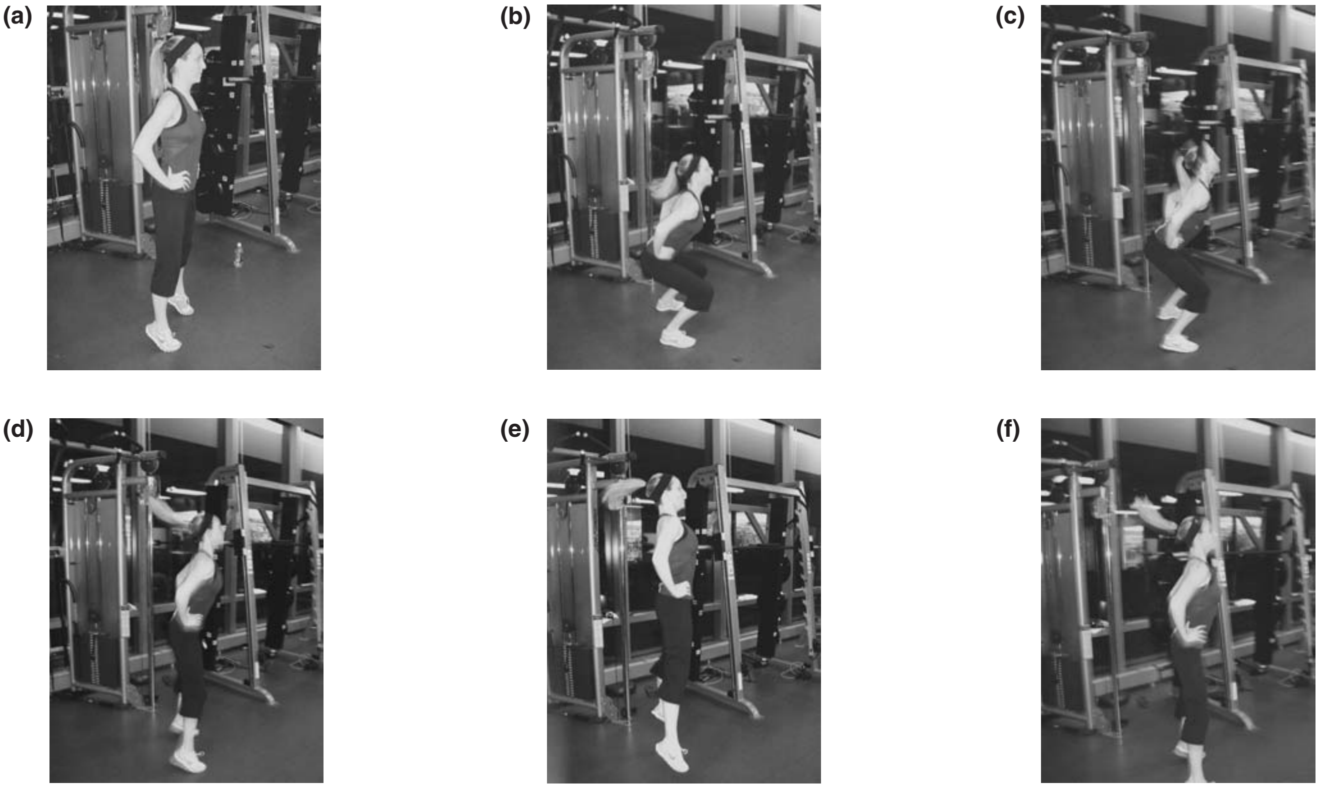
Plyometrics

The term *plyometrics* derives from the Greek roots *plio,* meaning "more," and *metr,* meaning "measure." Plyometrics, also known as the stretch-shortening cycle (SSC), is a form of conditioning for athletic improvement as well as for activities of daily living where quick and explosive movement is used in a progressive, sequenced manner to increase the acceleration and deceleration of an object or oneself. The fundamental necessity to increase jumping and/or throwing height, distance, or quickness is to increase power. The formula of power is

$$\text{Power} = \text{Force} \times \text{Velocity}.$$

To increase power, two variables may be improved: force or acceleration. Force may be improved by performing resistance or strength training. However, performing high-volume resistance training can adversely affect the ability to obtain full range of motion of any one joint in the body due to excessive muscular hypertrophy.



Countermovement jump.

Source: Photos courtesy of Samuel L. Berry, M.D.

Upper body plyometrics: overhead throw.

Source: Photos courtesy of Samuel L. Berry, M.D.

(j) (k) (l)

Upper body plyometrics: plyometric push-ups.

Source: Photos courtesy of Samuel L. Berry, M.D.

To increase power through plyometric training, two models of adaptation must be understood: mechanical and neuromuscular models of plyometric exercise.

In the mechanical model, the series elastic component (SEC) is the primary force-producing component in the SSC. Like a spring, the muscle is stretched, thus storing potential energy. For that potential energy to be converted to kinetic energy, a concentric muscle action must ensue immediately, otherwise the potential energy will be lost as heat.

The neuromuscular component of the SSC contributes through the stretch reflex, which is an involuntary reaction to the rate and magnitude of the stretch that occurs in a muscle. This rate and magnitude of stretch are sensed in the intrafusal muscle fibers, called *muscle spindles*. The quicker the rate of stretch felt in the muscle, the quicker the response to the stretch by the antagonist muscles, which co-contract as a protective mechanism to prevent musculotendonious damage to the stretched muscle. The stretch reflex is lost in a similar manner as it is in the SEC if there is a long delay between the stretch on the agonist muscle and a concentric muscle contraction. The potential energy in the form of the stretch reflex will be lost as heat.

The SSC embodies the stretch reflex as well as the SEC and has three very distinct and equally important phases to improve and manipulate plyometric training: eccentric, amortization, and concentric.

Eccentric Phase

The eccentric phase of the SSC sets up the second and third phases. This is where the agonist muscle gets the potential energy through the SEC and the stretch reflex begins, through the muscle spindle being activated and sending a signal to the spinal cord from the muscle that is being stretched. This is also called the *countermovement,* as when a person attempts to perform a vertical jump starting from a squatting position (see photos a through f).

Amortization Phase

The second phase of the stretch-shortening cycle is the amortization phase. This is the brief pause between the eccentric phase and the last phase, the concentric phase. The longer the amortization phase is, the more of the elastic energy that is lost. Therefore, it is essential to get a training response in plyometric training so that the pause is as brief as possible.

Concentric Phase

The last phase is the concentric phase. This is where the potential energy produced in the eccentric phase of the SSC is turned into kinetic energy. The signal that was sent to the spinal cord has now returned, and the SEC is now recoiling, to produce a powerful explosive movement. This is the takeoff of a vertical jump.

Without plyometric training interspersed throughout the training cycle, athletic development would be minimal at best, and the tendency to injury would be high in noncontact situations. Research supports the conclusion that plyometric training increases power production in anaerobic compared with aerobic athletes. Similar relative improvements may be seen in general populations in the activities of daily living as well as at the workplace. From getting out of a chair to climbing stairs quickly, the use adaptations from plyometrics for all ages and populations are positive. Conservative, low-intensity and low-volume plyometric training is best for prepubescent and osteoarthritic populations due to the lack of epiphyseal plate closure in long bones and low bone mineral density, respectively.

Prerequisites of Plyometric Training

When implementing plyometrics into a training program, it is important to know the training age of the individual who will be executing the exercise(s). If the participant has little or no training experience, then the use of plyometrics should be delayed to allow for the skeletal muscles and their tendons to adapt to the stress of resistance/strength training. General anatomical adaptation exercises must be implemented for 4 to 6 weeks prior to the execution of plyometrics to decrease the risk of injury.

Types of Plyometric Training

With sufficient anatomical adaptations, plyometrics may be executed for both the upper and the and lower body. Upper body plyometrics include, but are not limited to, exercises such as medicine ball overhead throws, plyometric push-ups (see photos g–i and j–l), and soccer throws. Essentially, any type of throwing pattern will elicit a plyometric adaptation. Lower body plyometric exercises are those that can be performed at very young ages, such as hopping, skipping, and jumping.

Although hopping, skipping, and jumping seem to be simple, unassuming activities, the intensity of their execution is what determines whether overuse or acute injury will result. High intensity and high volume in plyometric training often result in injury if not carefully monitored. In a properly designed nonlinear undulating training program, the propensity for injury due to plyometrics training is low. The frequency, intensity, type, duration, and age of training are important factors in deciding on the most appropriate plyometric training. With careful program design, the result will be increased performance in activities of daily living for general populations and greater athletic performance for both aerobic and anaerobic athletes.

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See also Conditioning; Exercise Programs; Performance Enhancement, Doping, Therapeutic Use Exemptions; Speed, Agility, and Speed Endurance Development

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Podiatric Sports Medicine

Podiatric sports medicine is the branch of podiatric medicine devoted to the study and practice of sports medicine; its practitioners are podiatrists with expertise in the foot and ankle areas. Important areas of understanding for the podiatric sports medicine practitioner include biomechanics, the physiology of sports and exercise, and surgery. Podiatric physicians are integral members of the sports medicine team at all levels of competition, including high school and college sports, youth sports, club sports, and professional athletic teams.

Podiatric sports medicine often assists those who are just beginning to undertake fitness as part of the treatment plan for systemic disorders such as postcoronary events, diabetes mellitus, obesity, and others. These new exercisers often need significant care to be able to continue to exercise. Foot and lower limb disorders are among the most common areas of injury for many athletes, especially runners.

The practice of podiatric sports medicine is exemplified by the American Academy of Podiatric Sports Medicine (AAPSM). The AAPSM defines its mission as advancing the understanding, prevention, and management of lower extremity sports and fitness injuries. The AAPSM sets out to accomplish its mission by supporting research in sports medicine and also in biomechanics, student education, and postgraduate education. The AAPSM began in 1970 with a founding core of podiatrists and the cardiologist George Sheehan, M.D. Sheehan was one of the first running gurus to appear on the scene. Shortly after beginning running, he developed foot and leg problems, which were treated by the sports podiatrist Richard Schuster, DPM. This relationship blossomed into a long association, focused on running, sports medicine, and sports podiatry. Sheehan championed podiatric sports medicine as having a large role to play in the understanding and treatment of lower limb disorders, especially in the treatment of patellofemoral pain syndrome (at that time one of the most common running injuries and commonly called *runner's knee*). In the 1970s, the primary focus of podiatric sports medicine was running, and the discipline grew right along with the running boom.

In the United States, there was no national sports medicine organization with physician participation until the 1950s, when the American College of Sports Medicine (ACSM) was founded. The AAPSM, founded some years later, ultimately forged bonds with the ACSM. The AAPSM has also forged close bonds with the National Athletic Trainers Association and the Special Olympics. The AAPSM is a participating member organization of the Joint Commission on Sports Medicine and Sports Science.

Prior to the founding of the AAPSM, and predating the foundation of the ACSM, there were a number of individuals who promoted the importance of care of the athlete and of those participating in athletic endeavors, including the soldier. One of the earliest uses of the X-ray was to define the "march" fracture, also known as a stress fracture. Although this was published by an orthopedist, the importance of the foot in sports was noted by Alfred Joseph, K. Burnett, and R. Gross as far back as 1918 in their textbook *Practical Podiatry*. This textbook included walking as a form of exercise. It included significant details on the treatment of the soldier. Foot hygiene, the importance of shoe fit, and the use of socks were key issues. Although it has been said that an army marches on its stomach, it won't march far with ill-fitting shoes and sore, blistered feet. Environmental issues were considered important, with trench foot being a problem at the time. Avoidance of infection and the treatment of skin problems were of paramount importance in the days before antibiotics. Some of these simple problems are a major issue for ultramarathoners. The authors noted that the foot had not received special attention prior to the 1900s and felt that it was about time.

The Boston Marathon, which began in 1897, is the oldest continuing marathon in the United States. The podiatrist Joseph Lelyveld began assisting with foot care issues in the first part of the 1900s and continued volunteering for 30 years. The podiatry tent at many marathons is one of the busiest places in the middle of the marathon course, and podiatrists have historically assisted at many of the nation's marathons.

Podiatric sports medicine physicians are active not only with many professional sports teams but also with athletes who face challenges and must overcome handicaps. The FitFeet program of the Special Olympics, begun by the podiatrist Patrick Nunan, DPM, screens the participants of the Special Olympics events. It has a presence at local, state, and international competitions. The AAPSM assisted in the foundation of FitFeet and supports its undertakings.

Other sports in which podiatric sports medicine plays an important role include skiing, hockey, figure skating, cycling, ultrarunning, and extreme survival running. Podiatrists are valued participants at the global desert ultraraces that take place in deserts on different continents, including the Gobi (China), Antarctica, Atacama (Chile), and Sahara (Egypt) deserts.

Podiatrists play a significant role in the development and advancement of athletic shoe technology and have worked with most major athletic shoe manufacturers. Bringing knowledge to the public and educating peers on sports injuries have always been of utmost importance to the leaders in sports medicine. Starting with the first educational meetings put on by the founders of the AAPSM, the educational push has been ongoing. Books directed at both the professional and the lay public have been published by many authors. Their impact on runners, running, and the view of the causes and treatment of injury was enormous. The AAPSM has developed a website that houses its popular athletic shoe lists. The AAPSM uses the Internet and multimedia to continue fulfilling its mission to educate the public.

While the historical basis of podiatric sports medicine has been biomechanics, there has been a trend toward increasing qualification in surgical skills. The sports medicine team is a diverse one. The increasing interest in genomics, applied physiology, and many other disciplines contributes to our advancement in the knowledge, understanding, and treatment of the athlete. However, the special understanding of foot and lower limb function, biomechanics, training regimens, shoe structure and function, and foot and ankle structure, function, and injury makes the podiatric sports physician a valued member of the team.

Stephen Pribut

See also Athletic Shoe Selection; Careers in Sports Medicine; Foot Injuries; Orthotics

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Posterior Cruciate Ligament Injuries

Posterior cruciate ligament (PCL) injuries are less common than anterior cruciate ligament (ACL) injuries and generally are not as debilitating. The PCL is important for stability of the knee and for maintaining the tibia in its correct position anterior to the femur.

Anatomy

The PCL is one ligament that consists of two distinct bundles, one bundle working in flexion and the other working more in extension. The ligament originates from the femur and inserts on the back of the tibia.

Biomechanics

The PCL is the primary restraint to posterior tibial translation. The lateral collateral ligament and the posterolateral knee structures, including the popliteus tendon and capsule, are the secondary restraints, with the medial collateral ligament playing a lesser role.

Epidemology

PCL injuries often remain undetected. A 2% to 5% incidence of undetected PCL injuries has been noted in elite college athletes. Fanelli and Edson conducted a prospective analysis in 1995 of the incidence of PCL injuries in patients presenting with an acute hemarthrosis (swelling) of the knee. In this cohort, PCL injuries were present in 38% of cases. Trauma patients represented 56.5% of these injuries, and 32.9% were related to sports. Isolated PCL injuries were rare (3.5%), whereas 96.5% of PCL injuries occurred in combination with other ligament injuries. The activity most frequently associated with PCL injury is football, followed by baseball, skiing, and soccer.

Mechanism

Damage to the PCL may occur by any of several different mechanisms, including both low- and high-energy injuries in which a posteriorly directed force is applied to the proximal tibia of a flexed knee. This may happen when an athlete falls with the foot in a flexed position or as a result of a "dashboard injury" (when a flexed knee hits the dashboard) during a motor vehicle accident.

The mechanisms underlying combined ligament injuries involving the PCL are usually a combination of a posteriorly directed force applied to the tibia in conjunction with a sideward or a torsional force. These combined forces may result in injury to the ACL, collateral ligaments, posterior capsule, or posterolateral corner/structures (PLC).

Assessment

History

The details of the initial injury should be obtained to determine the magnitude of energy exchange during the event and, consequently, the potential extent of injury to the stabilizing structures of the knee. The majority of injuries to the PCL involve other ligamentous injuries, and higher-velocity trauma may be more likely to result in combined injury.

Symptoms of PCL deficiency include pain, stiffness, and swelling in the knee. Instability is occasionally noted but with less frequency than in ACL deficiency.

The first presentation of a chronic injury may be with symptoms of osteoarthritis.

Examination

The posterior drawer test is the most accurate test for a PCL injury and is performed with the patient lying on his or her back with the knee at 90°. The examiner places his or her hands on the proximal tibia and applies a posterior force. The degree of posterior translation of the tibia is noted relative to the femur.

Grade I PCL laxity is consistent with translation of 0 to 5 millimeters (mm) (the tibial condyle remains anterior to the femoral condyle). Grade II is classified by posterior translation of 6 to 10 mm (the tibial is flush with the femoral condyle). Grade III injuries measure >10 mm of posterior translation (the tibia plateau is posterior to the femoral condyle).

As a patient with an acute knee injury suffers a lot of discomfort, the posterior Lachman test is more often advised. It is carried out in a similar manner to the draw test, but the knee is only bent to 30°.

The posterior sag test is a static test and looks for posterior sag of the tibia relative to the femur with the knee bent to 90°. Generally, comparing the injured knee with the uninjured side is helpful.

To identify combined injuries, the integrity of the other ligaments around the knee should be tested.

Imaging Studies

Plain X-rays may reveal a bony avulsion of the ligament off the back of the tibia, posterior translation of the tibia relative to the femur, or signs of injury to other ligaments. In patients who have a chronic tear of the PCL, there may be changes consistent with osteoarthritis of the tibiofemoral compartment or the patellofemoral joint.

Stress radiography is a useful testing method for objectively determining the amount of posterior tibial translation of the knee. A machine places a posterior force on the tibia, and a lateral X-ray is taken simultaneously. The position of the tibia relative to the femur can then be measured.

Magnetic resonance imaging (MRI) has been proven to be 99% accurate in diagnosing acute injuries of the PCL. Information regarding the integrity of the other ligaments around the knee can also be obtained. MR images can also provide useful information of prognostic value in predicting the capacity for healing. It has been shown that rupture of a single PCL bundle is more likely to result in a satisfactory outcome than complete rupture involving both bundles.

Treatment

Nonoperative Treatment

Unlike the ACL, the PCL can heal after injury. Shelbourne and colleagues found that only 2 weeks after injury, patients often have no pain and also demonstrate a firm end point on posterior drawer testing. Continuity of the PCL was found in 37 of 40 patients who had an MRI evaluation at a mean of 3.2 years after injury. The actual time it takes to obtain PCL continuity after acute injury is not yet known.

Shelbourne and colleagues evaluated 271 patients at a mean follow-up of 7.8 years after acute isolated Grade 2 PCL injuries. All patients were treated nonoperatively. The patients were allowed to return to their previous activities and sports as tolerated after attaining a good range of movement and strength. The authors found little change in the PCL laxity grade from the initial injury to the final examination. There was no correlation between objective and subjective knee function and the PCL laxity grade. No correlation was found between radiographic evidence of arthritis and the grade of laxity. The presence or absence of degenerative changes on radiographs did not significantly affect the total scores. Regardless of the amount of the laxity, 50% of the patients were able to resume sports at the same level or higher.

Conservative treatment of acute PCL injuries emphasizes reducing swelling and regaining full knee range of motion, leg strength, and control. Immobilization is rarely required for an isolated PCL injury, although some patients feel more comfortable with an immobilizer and crutches during the first week. As the swelling and pain subside, range-of-motion exercises and leg-strengthening exercises are instituted, with an emphasis on the quadriceps.

During physical therapy, it is important to minimize posterior tibial translation by protecting against gravity-induced posterior tibial sag and by avoiding open–kinetic chain hamstring exercises. Closed–kinetic chain exercises, such as the squat between 0° and 70°, in which the foot is fixed, produce less force on the knee.

In some patients, use of a higher-heeled boot or shoe to increase the activity of the quadriceps muscle during walking may help alleviate symptoms. Patients who have symptomatic instability may benefit from use of a four-point brace, but objective data and long-term follow-up studies on this mode of treatment are lacking.

Patients with greater quadriceps muscle strength show better results after a PCL injury. Return to sports is often achieved by 3 months.

Operative Treatment

Bony Avulsion Injuries

Patients in whom the PCL is avulsed from the back of the tibia with a bone fragment can have an excellent result with primary operative management if the fragment can be anatomically restored to its bed. If the fragment is large enough, a single screw is usually sufficient for effective fixation. For smaller fragments of bone or cartilage, sutures pulled through drill holes have been used effectively.

Isolated Injuries of the PCL

For those patients with acute or chronic Grade III injuries and symptomatic instability, single-bundle, PCL reconstruction seems to improve both subjective knee function and posterior tibial translation in the short term. However, some patients may continue to demonstrate residual laxity, and there is no definitive evidence to suggest that PCL reconstruction significantly alters the natural history of the PCL-deficient knee.

There are two main methods of reconstructing the ligament. One is an arthroscopic technique performed by drilling tunnels in the tibia and femur from the front of the knee, through which a graft is passed. Alternatively, reconstruction can be carried out via a combined open and arthroscopic surgical approach from behind and in front of the knee. No differences in outcomes have been reported for the different methods of reconstruction, and it is currently not known which tendon graft is optimal. Recent interest in reconstructing both bundles of the PCL has failed to provide any further benefit.

Martyn Snow

See also Anterior Cruciate Ligament Tear; Knee Injuries; Knee Ligament Sprain, Medial and Lateral Collateral Ligaments; Musculoskeletal Tests, Knee; Sports Injuries, Acute

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Posterior Impingement Syndrome

This disorder is caused by anything that creates compression of the shoulder anatomy (e.g., muscles, tendons, nerves, or blood vessels). Other potential causes include imbalances between the muscles that permit shoulder motion and those that provide stability to the joint. These include the rotator cuff muscles, such as the infraspinatus and supraspinatus, which may cause friction against the posterior-superior part of the glenoid and glenoid labrum.

The wing bone (scapula) and collar bone (clavicle) create an arch at the tip of the shoulder, through which tendons and nerves pass, usually with ease. The posterior border of the arch is the head of the humerus.

Understanding the mechanism of the injury is important, requiring familiarity with the basic related anatomy. The shoulder is a ball-and-socket joint. The glenoid fossa (cavity) of the scapula (shoulder blade) is the socket and is composed of bone at the base and lined with cartilage. This is surrounded with additional lining at the circular rim by the glenoid labrum (from the Latin meaning "upper lip"), which is composed of cartilage. This makes the socket deeper, affords more stability to the joint, and provides easier movement to the ball part of the joint, with minimal friction. The ball of the joint is the proximal part of the humerus (upper arm bone) that is embedded in the glenoid fossa and surrounded by the glenoid labrum.

Several muscles and ligaments help in joint stability, serving to either initiate or maintain motion and providing a balance of forces, which permits the ball to remain in the socket. Major involved muscles include the deltoid, biceps, and supraspinatus.

The synchronous action of the ligaments and muscles provides stability and strength to the shoulder and permits a wide range of motion, including abduction (away from the body), adduction (toward the body), and internal and external rotation. The main shoulder muscles are as follows:

1. The deltoid, which covers the shoulder joint and provides a smooth contour of the shoulder, originates from the humerus and inserts into the shoulder joint, thus covering it from three surfaces.
2. The supraspinatus (part of the rotator cuff muscles, along with the infraspinatus, teres minor, and subscapularis) originates at the wing bone, passing under the acromion, and inserts into the ball of the humerus. It causes abduction of the arm and is the most commonly injured rotator cuff muscle.
3. The infraspinatus originates at the shoulder blade and inserts at the humerus head (ball) and is encapsulated by the shoulder joint under the coracoacromial arch, which laterally rotates the arm.

The fact that the passage of these structures occurs through a narrow area places them at a high risk of injury. Overuse of the shoulder muscles and ligaments as well as the underlying bursae (fluid-filled sacks that serve as shock absorbers) also contributes to the risk of injury. Anything else that decreases the space in the shoulder joints, such as calcification or bony spurs, may cause potential problems. Individuals who use their arms frequently, such as swimmers and baseball pitchers, are primary candidates for shoulder impingement syndrome.

Tendons connect bone to muscle and transmit force when muscles contract. Repeated use of a tendon may cause tendinitis (inflammation of the tendons). Other injuries may occur from excessive strain on the tendon. For example, if a person attempts to lift a heavy box, force will be exerted on the tendon and the area of insertion, which in this case is the glenoid labrum. A possible injury could occur. The tendon could get inflamed and begin to tear from the area of insertion of the glenoid fossa (cavity). The shoulder has two sets of muscles and ligaments, with differing functions. One set holds the joint in place, while the other permits free motion of the shoulder and upper arm in all directions with ease.

Many factors come into play to ensure good shoulder movement.

1. Sufficient subacromial arch outlet space
2. Smooth synchronization and proper balance (pull and push) around and inside the shoulder joint
3. A firm, but not too tight, coupling between the wing bone and the ball of the humerus
4. The labrum in good condition
5. No bony spurs or calcification in the space under the coracoacromial arch

The most common type of impingement syndrome is posterior-superior impingement syndrome. This is directly associated with the rotator cuff muscles and tendons and causes posterior shoulder pain. The primary cause of this impingement is the compression of the supraspinatus and infraspinatus tendons under the coracoacromial arch. Posterior shoulder pain is often elicited by elevation of the arm.

Causes and Etiology

There are several pathological changes that occur in the area of the subacromial arch (especially in the very active population) due to age, such as bony spurs and bursitis. Other contributory factors include compromising the depth of the subacromial space, degenerative joint disease, arthritis, and rotator cuff muscle atrophy and weakness. Even external factors, such as a severe kyphosis (bending forward) of the upper and midback, can apply tension to the scapula, leading to pressure in the area of the origin of the rotator cuff muscles. Poor form during weight lifting and repetitive overhead motion in athletes, especially baseball players and swimmers, cause excessive external rotation of the humeral head and eventually lead to decreased internal rotation.

The key to diagnosing this syndrome lies in knowing the mechanism of injury. Typically, it is caused by overuse and repetitive movements that cause stress of the shoulder, especially those that cause the arm to be elevated. One must keep in mind that the stability of the shoulder depends on the strength of the rotator cuff muscles and glenohumeral ligaments—stresses may cause instability, which in turn predisposes to injury.

Medical History and Patient Presentation (Symptoms and Signs)

Patients may complain of posterior shoulder pain that gets progressively worse, especially with activities. Patients may also have a feeling of weakness when trying to lift a box overhead or with activities such as swimming. Patients generally present without any history of trauma or surgery and state an insidious onset of symptoms.

Physical exam should include the following:

1. Inspect the shoulder for any signs of trauma/swelling, and compare the affected side with the uninvolved side for asymmetry.
2. Evaluate range of motion in all directions, both actively and passively.
3. Evaluate muscle strength of the rotator cuff muscles and deltoid.
4. Conduct sensory testing for the nerves that pass under the coracoacromial arch to rule out any nerve injuries.
5. Evaluate blood circulation to rule out any compromise in the affected arm.
6. Palpate the shoulder joint for localization of tenderness.
7. Perform appropriate special screening tests based on the clinical presentation, including the following:
    - *Infraspinatus stress test:* Force is placed on this muscle to elicit pain.
    - *Supraspinatus stress test:* The patient's arm is supported until it is above his or her shoulder level, and then the examiner lets the arm drop while the patient tries to hold it up. (A positive test is one in which the patient cannot hold the arm up.)

- *Stress testing of ranges of motion of the joint:* Apley scratch test is used to determine all ranges of motion of the shoulder.
- *Impingement test:* A slight passive (by moving the arm) elevation motion with slight internal arm rotation will either reproduce the pain or worsen it.
- *Jobe relocation test:* This test is used to check for anterior instability of the shoulder. The arm is held at 90° by the examiner. Then, a posterior (back) force is applied on the humerus head as the patient tries to return the arm to its normal position. The pain actually is reduced because the pressure on the head of the humerus is relieved. Thus, easing of pain signifies a positive test.

In addition to the above tests, radiologic studies, such as shoulder X-rays and/or magnetic resonance imaging (MRI), may be appropriate if needed for definitive diagnosis.

Coupling the history, severity of symptoms, and physical exam with radiologic studies will provide the stage of the diagnosis of the impingement, which allows for management of the condition.

Stage I: In this stage, some feeling of stiffness with activity is noticed, and a slow warm-up for activities may be essential.

- The athlete should stop activity for at least 2 to 4 weeks to evaluate and strengthen the rotator cuff muscles, in addition to taking anti-inflammatory medications.

Stage II: In this stage, mild posterior shoulder pain that worsens with overhead activity is noticed. Anterior shoulder instability is examined by the Jobe relocation test.

- The athlete should stop activities for at least 4 to 12 weeks and needs a very detailed and appropriate rehabilitation program based on the presentation and physical exam.

Stage III: This stage consists of moderate to severe shoulder pain that worsens with any movement in any direction. Anterior shoulder instability is examined by the Jobe relocation test. If the condition does not improve in 12 weeks' time, then a rehab program is advised.

- The athlete, in addition to the above interventions, will consider surgical procedures such as anterior-capsulo-labral reconstruction and thermal capsulorrhaphy (which basically shrinks the capsule so that it will be decompressed on the head [ball] of the humerus), so that there will be more space for the tendon to pass easily to prevent rubbing on the bones. Another surgical intervention is acromioplasty, which is the removal of a part of the acromion, which in turn would decrease the pressure on the tendon and finally enlist an appropriate rehabilitation program with more detailed monitoring, evaluation, and reevaluation of the progress. The patient should have minimal activity for 1 month.

The key to avoiding such an injury from occurring is prevention. Proper warm-up and strengthening of the shoulder muscles and ligaments are crucial. In addition, starting slow, increasing activity gradually, and avoiding excessive repetitive motion will certainly decrease the likelihood and severity of injury.

George Kolo

See also Frozen Shoulder; Rotator Cuff Tendinopathy; Shoulder Injuries

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Posterior Tibial Tendinitis

Posterior tibial tendinitis is a source of pain in the medial (or inner) portion of the foot and ankle. A tendon is a strong piece of fibrous, connective tissue that attaches muscle to bone. The tendon arises from the posterior tibial muscle. This is a muscle in the lower leg, which plays an important role in moving the foot in inward and downward directions. These motions are known as inversion and plantarflexion, respectively. Tendinitis refers to inflammation of the tendon, which is thought to be the source of pain. The injury may be induced by trauma or, especially in athletes, may be the result of overuse due to the excessive mechanical stress placed on the tendon. There is a sheath that surrounds the tendon, and if this becomes inflamed, it is referred to as a *tenosynovitis*. When this injury becomes chronic, there are significant degenerative changes within the tendon. This condition is referred to as *tendinosis* or *tendinopathy*. Therefore, it is common to see this injury described as such. This condition is most commonly seen among those above 40 years of age but is also frequently encountered in younger athletes.

Anatomy

The posterior tibial muscle is a large muscle of the lower leg that is the primary invertor of the foot and plays a key role in plantarflexion. It gives rise to the posterior tibial tendon in the lower one third of the leg, in an area just above the medial malleolus, a bony protuberance on the inner half of the ankle (Figure 1). Within its sheath, or covering, the tendon traverses behind the medial malleolus and then inserts into the medial arch of the foot. Specifically, it mainly inserts into the navicular bone on the inner half of the foot. From there, it splays into smaller attachments that connect the midfoot with the bones closer to the toes. It also has insertions that play an important role in supporting the medial arch of the foot. Additionally, the tendon also serves as a shock absorber to prevent excessive motion of the foot while running. All these different forces cause the posterior tibial tendon to be placed under a great deal of mechanical stress. Athletes who participate in activities that emphasize running, cutting, or jumping are prone to such injuries.

Causes

As previously stated, the posterior tibial tendon is under significant stress and plays a key role in a number of foot movements. Therefore, posterior tibial tendinitis is usually the result of repetitive stress on the tendon. This injury is generally thought to be due to overuse, as it is not commonly seen in younger people unless they engage in sports that warrant rapid changes in direction, such as basketball and soccer. It is also common among skaters and dancers as they place excessive stresses on their feet. It is a frequent injury in runners, with 2% to 4% of all participants estimated to be affected. They may have excessive motion of the foot, which is described as *overpronation*. Those who have occupations that necessitate extended periods of standing are also at risk. Obesity, pes planus (flat feet), and various types of arthritis are all felt to predispose people to posterior tibial tendinitis.

Although the majority of cases are the result of overuse, some cases of posterior tibial tendinitis

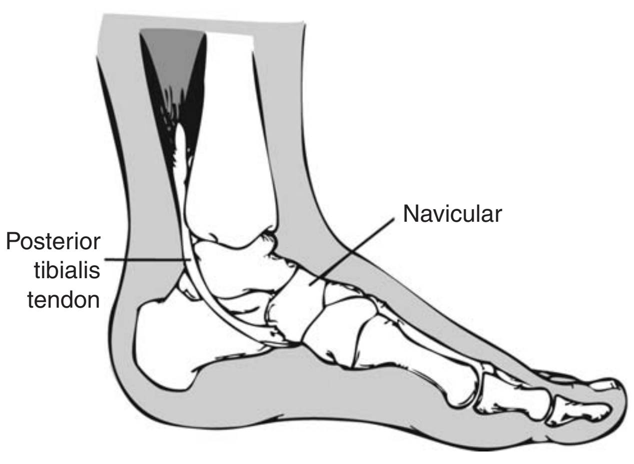

Figure 1 Posterior Tibial Tendon

Source: Jonathan A. Becker, M.D., University of Louisville.

Note: An overview of the anatomy of the posterior tibial tendon, showing its insertion into the navicular bone.

are due to acute trauma. The tendon becomes vulnerable when the foot is rapidly moved outward and upward. This can stretch the tendon, leading to acute injury or, at its worst, a complete tear or rupture.

Symptoms

The most common symptom of posterior tibial tendinitis is pain over the medial portion of the foot. This pain is generally seen near the insertion of the tendon into the midfoot or the area just below the medial malleolus. However, pain can be located over any portion of the tendon and is often not confined to a discrete area. A minority of patients may report a traumatic episode as their etiology. Pain will generally increase with activity or sports participation and resolve with rest; it can present with severity that ranges from mild to debilitating. Most often, the patient will have had symptoms for a number of weeks or months at the time of presentation. In cases where there is acute inflammation or a tenosynovitis, there may also be redness and swelling. Certain motions, such as moving the foot inward or standing on one's toes, may be reported as particularly painful. In advanced cases, there may be a loss of the arch, or flattening of the foot. Posterior tibial tendon problems are one of the most common reasons for a person to develop flat feet.

Diagnosis

Posterior tibial diagnosis is usually done on the basis of the patient's history and physical exam. Most frequently, the patient participates in an activity that places excessive stress on the feet, such as running, skating, or dancing. A recent increase in activity or alteration in footwear or cleats may be noted as well. There will be tenderness over some portion of the posterior tibial tendon. Having the patient plantarflex and invert the foot will induce pain. The examiner may provide resistance to help provoke the symptoms. Discomfort can also be elicited by having the patient attempt to bear weight on his or her toes. In settings of acute inflammation or tenosynovitis, there may be redness or swelling. Weakness may also be noted on any of these provocative movements. Acute rupture of the tendon will often present not only with pain but also with significant swelling and marked weakness, especially when the patient tries to stand on his or her toes.

Anatomical changes may be noteworthy on exam. These may have been acquired secondary to incompetence of the tendon or may be anatomical abnormalities that predisposed the patient to the problem. These include pes planus or the appearance of a "too many toes" sign. The latter refers to the appearance of the feet when examined from behind with the patient standing. The inner part of the foot will sag with loss of the arch, and more of the outer toes of the foot will be visible from behind the heel. The foot will be in an everted, or outward pointing, position. The gait should be observed closely for evidence of flattening of the arch or overpronation.

Generally, imaging is not necessary to diagnose posterior tibial tendinits. X-rays will not visualize the tendon but may be useful in ruling out other sources of pain such as arthritis or fracture. Magnetic resonance imaging (MRI) will visualize the tendon and can be useful in delineating the extent of tendinitis or tendinopathy. It is also useful for determining if the tendon has been ruptured.

Treatment

Regardless of the severity of symptoms, initial management will be similar for most cases. Relative rest from the offending activity and frequent application of ice will allow for symptom control. Nonsteroidal anti-inflammatory drugs (NSAIDs) are helpful for treating the pain and may be particularly beneficial in cases of tenosynovitis. Elevation will reduce swelling. Improved shoe fit and arch supports are helpful even in cases where there is no evidence of pes planus, as they may assist in the supportive role of the posterior tibial tendon. For athletes, this can also be accomplished with taping. Participants who use cleats may consider wearing alternative shoes for conditioning and practice and reserving the use of cleats for competition, as this may play a role in the etiology. An exercise program that promotes stretching of the posterior calf muscles and strengthening of the foot muscles will provide rehabilitation. The goal is to improve muscle and tendon strength and mobility.

In more severe cases, crutches or a short leg walking cast may be used to alleviate symptoms for those with debilitating pain or for those who have pain with routine activities of daily living. Physical therapy may be employed to provide an exercise program, as well as modalities such as ultrasound or iontophoresis (introduction of pain-relieving medications through the skin). There is conflicting evidence regarding the benefits of those treatments. Also, consideration ought to be given to fitting the patient with a custom-made orthotic. For cases with advanced inflammation of the tendon sheath, a local steroid injection may be employed to relieve pain. However, these injections place the patient at risk for tendon rupture, prompting some experts not to recommend them. The time course for resolution of symptoms, especially in more severe cases, can vary from weeks to months. Generally, the longer those symptoms are present at the time of presentation, the longer it will take for recovery. Return to activity is based on the level of discomfort. Once any lost strength or range of motion has been regained, patients can advance their activity level as their symptoms allow.

Surgery is reserved for severe cases that are refractory to more conservative measures or those with complete rupture of the tendon. Surgical techniques may include repair of the tendon and reinsertion into the navicular bone. After surgery, it will be approximately 3 months before return to normal activity.

Jonathan A. Becker

See also Lower Leg Injuries; Sports Injuries, Overuse; Tendinitis, Tendinosis

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Posterolateral Rotatory Instability

Posterolateral rotatory instability (PLRI) is the most common type of chronic lateral elbow instability. It has been well-defined in the literature by O'Driscoll and others since 1991, yet our understanding of the pathophysiology and biomechanical abnormalities associated with this injury is still evolving. PLRI is part of a spectrum of injury to the soft tissues of the lateral elbow, primarily the lateral ulnar collateral ligament, usually following a traumatic elbow injury, such as an elbow dislocation. There are three stages of PLRI: (1) posterolateral subluxation, (2) incomplete dislocation with the coronoid lodged beneath the trochlea, and (3) complete dislocation of the elbow joint with the coronoid located behind the humerus.

In children, the elbow is the most commonly dislocated major joint, whereas in adults, the elbow is the second most commonly dislocated joint, after the shoulder. Dislocations represent about 10% to 25% of all elbow injuries. Like other upper extremity injuries, elbow dislocations can occur from direct trauma, a FOOSH (fall on an outstretched hand) injury, or a strong directional or levering force on the elbow. Elbow dislocations typically occur in children older than 13 years, after the physes around the elbow are closed. However, it is not uncommon to sustain a combined elbow fracture and dislocation. The highest incidence of elbow dislocations is in the under-20 age-group, and the majority are associated with sports activity. In general, prompt closed reduction of simple elbow dislocations results in favorable outcomes; however, when residual instability persists despite a period of proper immobilization, then significant dysfunction can develop. Complications include loss of range of motion (ROM), structural instability, nerve palsies, and muscular weakness.

Other causes of PLRI include apparent "elbow sprains," prior tennis elbow release, radial head excision, and multiple corticosteroid injections in the lateral elbow. Finally, PLRI has been associated with congenital or acquired cubitus varus deformities, which can develop secondary to supracondylar fractures in children.

Anatomy

The elbow is one of the most complex joints in the body, consisting of three articulations: (1) ulnotrochlear, (2) radiocapitellar, and (3) proximal radioulnar. Ulnotrochlear (ulnohumeral) joint instability results in PLRI due to lateral ulnar collateral ligament (LUCL) complex injury. The LUCL complex consists of four structures: (1) the LUCL itself, (2) the annular ligament, (3) the radial collateral ligament, and (4) the accessory lateral collateral ligament (LCL). The posterolateral joint capsule, capsular insertion of the annual ligament, and common extensor origin function as secondary soft tissue restraints to the lateral elbow.

Elbow flexion/extension occurs mainly at the ulnohumeral and radiocapitellar articulation, whereas forearm pronation/supination involves the radiocapitellar and proximal radioulnar articulation. Normal ROM of the elbow is approximately 150° of flexion to 0° of extension, 90° of forearm pronation, and 90° of forearm supination. The elbow provides attachment sites for various muscle groups and ligaments. The primary stabilizers of the elbow are the ulnotrochlear articulation, medial collateral ligament (MCL), and LCL. The radial head and the surrounding muscle bundles make up the secondary stabilizers of the elbow. Supination of the ulna results in a posterolateral displacement away from the trochlea in PLRI.

Clinical Evaluation

Elbow dislocations on physical examination may have an obvious deformity, diffuse joint pain and swelling, decreased or painful ROM, and crepitus. The normal anatomic triangle that is formed by the radial head, lateral epicondyle, and distal lateral tip of the olecranon process is disrupted with elbow dislocations. Any athlete who sustains trauma to the upper extremity and presents with any of these signs or symptoms should be evaluated for the possibility of an elbow fracture or dislocation. With such injuries, the examining physician must also assess the entire upper extremity for associated injuries; however, the instability associated with PLRI is not usually immediately evident due to the severity of pain present acutely; thus, physicians must have a high index of suspicion and monitor the patient for signs of instability during the recovery period.

The presenting history of PLRI patients varies from chronic elbow pain, clicking, catching, or snapping to a spectrum of giving way/subluxation with extension/supination or even a compensatory flexion forearm pronation contracture. The most reliable maneuver to reproduce instability symptoms is to have the patient push off on armrests as he or she rises from a chair. Physical examination for PLRI includes palpation for tenderness along the LUCL followed by provocative testing. The lateral pivot-shift test is the most sensitive examination technique described. The patient is placed in a supine position with the shoulder in external rotation and the arm overhead. The elbow starts fully extended and supinated. A valgus supination and axial compression force is generated as the elbow is flexed. Rotary subluxation of the ulnohumeral joint may be reproduced at approximately 40° of flexion, with pain and prominence of the radial head noted. Further flexion actually reduces the joint. Patients often experience significant apprehension during this maneuver.

The push-up sign occurs when apprehension, subluxation, or dislocation occurs on terminal elbow extension from a flexed position in a wide-shoulder push-up position. The chair sign is when the patient arises from a seated position by pushing the arms of the chair with the elbows flexed 90°, with the forearms supinated and arms abducted. This test yields a positive result when apprehension, subluxation, or dislocation occurs.

Radiographs

Standard anteroposterior and lateral views of the elbow should be sufficient to diagnose most elbow dislocations. Radiographs of the forearm may be necessary to evaluate for associated fractures. Computed tomography (CT) with three-dimensional reconstructions can be helpful in assessing for intraarticular fragments and the congruity of the articular surfaces. Approximately 10% to 20% of elbow dislocations have an associated fracture.

Typical fractures associated with elbow dislocations are radial head, olecranon, medial/lateral epicondylar, and coronoid process fractures. Elbow dislocations, specifically dislocation of the ulnohumeral joint, are described based on the position of the olecranon with regard to the humerus (posterior, anterior, lateral, and/or medial). The posterolateral elbow dislocation is the most common. It is rare to have a divergent dislocation where the radius and ulna are separated from one another and the humerus.

Continuous fluoroscopy during the pivot-shift test and stress radiographs may be useful to confirm the diagnosis of recurrent elbow instability. Widening of the ulnohumeral joint or posterior subluxation of the radial head demonstrates PLRI. Magnetic resonance imaging (MRI) has a limited role in demonstrating PLRI, as it is difficult to assess the true extent of LUCL complex injuries.

Treatment

Immediate treatment consists of using a hinged elbow brace and keeping the forearm in full pronation for a period of 4 to 6 weeks to maintain the reduction. Prolonged immobilization can adversely affect outcome and time to recovery for simple dislocations, but longer immobilization times are indicated in the setting of LUCL injury and instability. Surgical stabilization is indicated in active patients who are symptomatic with recurrent instability, pain, and functional limitations. Primary LUCL repair is difficult unless it is performed within days to weeks of the initial injury; thus, the vast majority of surgical treatments involve reconstruction of the LUCL complex. A typical recovery period ranges from 3 to 6 months and involves extensive physical therapy, progressing with joint stability exercises, strengthening, ROM, and progressing to sport-specific multiplanar exercise, such as throwing.

Urgent orthopedic referral is indicated for any elbow that remains unstable, has redislocated, or has entrapment of either fractured fragments or soft tissue within the joint. Long-term complications include stiffness, recurrent pain, arthritis, myositis ossificans, recurrent instability, ligament damage, contractures, and nerve injury.

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See also Elbow and Forearm Injuries; Elbow and Forearm Injuries, Surgery for; Musculoskeletal Tests, Elbow

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Postgame Meal

Recovery from training is the period when one achieves the maximum results. Postworkout nutrition has gained significant attention. A postworkout meal is intended to help the body in increasing protein synthesis, creating more of an anabolic state, and making the most of the body's desire to repair itself.

The meal after an athletic event, be it practice, workout, or competition, is a deciding factor in the potential gain that is being achieved and in the recovery process. Gaining strength and muscle does not occur during a workout, but after, during the recovery stage. After the event, it is important to have a meal that fulfills several needs. It should help provide the energy needed for rapid replenishment of glycogen stores, stop protein breakdown, compensate for loss of fluid and salts, and increase protein synthesis. Ideally, the postevent meal occurs within 30 minutes and again within 2 hours.

Goals

Replenishing Glycogen Stores. A postgame meal delivers energy to the muscles as quickly as possible (within 30 minutes and again within 2 hours) to help rebuild muscle energy stores for the next workout.

Rehydration. Drink 16 ounces (oz; 1 oz = 28.35 grams [g]) of water for each pound (lb; 1 lb = 0.45 kilograms [kg]) lost. One half of the fluid loss should be replaced in the first 4 hours, the other half over the subsequent 8 hours.

Timing

Many inexperienced athletes do not understand that gaining strength and muscle occurs after a workout, during the recovery stage. The timing of a postevent meal is crucial.

It is important to consume a portion of the postevent meal immediately after exercise. During this time, the muscles are biochemically "primed" for nutrient uptake. The muscles are depleted and require an abundance of protein and carbohydrate. This phenomenon is commonly known as the "window of opportunity." This window gradually closes as time passes. Failing to eat immediately after exercise diminishes the chances for promoting optimal recovery. A postexercise meal taken immediately after working out is superior to a meal consumed just 1 hour later. A meal taken 1 hour after the event is superior to the same meal consumed 3 hours later.

Immediately after physical activity, it is advised to consume a liquid meal that is quickly absorbed.

Two hours after the competition or workout, a well-balanced meal with complex carbohydrates and protein is recommended.

When a prolonged period of recovery is scheduled (e.g., a bye week or weekend), a slower-releasing casein protein drink, such as milk, would be better.

If athletes are going to take a few days off between intense training sessions, the timing of the postevent meal becomes less important. As long as sufficient carbohydrates are provided throughout the day, the timing of carbohydrate ingestion does not affect the amount of glycogen stored.

- Take 100g carbohydrates in the first hour, then every 2 to 4 hours
- Consume high–glycemic index (GI) carbohydrates immediately, low-GI carbs as tolerated
- Replace fluid at 16 oz per pound lost
- Take 1 g of salt and 16 oz of fluid for each pound of weight loss over 5 lb
- Maintain the ratio of carbohydrate to protein as 3:1

Carbohydrates

Successful athletes, regardless of their chosen sport, take their postexercise nutrition seriously. All forms of exercise use carbohydrates for energy, resulting in muscle glycogen depletion. The post-workout meal should be high in carbohydrates to replenish the muscle energy stores.

The rate of glycogen synthesis peaks immediately following exercise. The athlete should consume about 100 g of high-GI carbohydrates in the first hour and every 2 to 4 hours thereafter. The addition of complex solid carbohydrates can be as tolerated over time.

Consumption of 1 g of glucose per kilogram of body weight after exercise and every 2 hours for 6 hours afterward improves the muscle glycogen stores. The same amount of fructose increases the liver glycogen stores. The addition of protein raises the insulin response, which may further increase the glycogen stores.

The carbohydrates that work best are dextrose and maltodextrin (taken in a 50:50 balance). These two carbohydrates also create an insulin spike. When simple sugars such as maltodextrin and dextrose are ingested, insulin is released into the bloodstream, making sure that blood sugar does reach dangerous levels.

Insulin is highly anabolic at rest, which means that it helps build muscle and stops protein breakdown after exercise. Consuming a large amount of carbohydrates leads to a large insulin release, increased glycogen storage, and increased protein repair. A carbohydrate intake of 0.8 to 1.2 g/kg of body weight maximizes glycogen synthesis and accelerates protein repair. Additional carbohydrates that exceed the storage capacity are converted to body fat. Creating an insulin spike too frequently decreases insulin sensitivity.

Protein

Protein is a key "building" nutrient for a variety of bodily tissues, many of which support muscle growth (enzymes, skin, hair, nails, bones, and connective tissue are all constructed from protein). Protein constitutes 15% to 20% of the body weight and follows water as the body's second most abundant substance.

The current U.S. recommended dietary allowance (RDA) for protein is 0.8 g kg^{-1} day^{-1}. Athletes participating in different sports have different needs. A strength athlete requires about 2 g kg^{-1} day^{-1} of protein, whereas an endurance athlete needs only 1.5 g kg^{-1} day^{-1}. The daily caloric intake from protein should be 150 to 250 g/day.

Since muscle protein is degraded during exercise, the addition of a relatively large amount of protein to the postexercise meal is important to help rebuild the structural aspects of the muscle. After exercise, the body decreases its rate of protein synthesis and increases its rate of protein breakdown. The provision of protein and amino acid solutions has been shown to reverse this trend, increasing protein synthesis and decreasing protein breakdown. Stopping protein breakdown is achieved with the help of insulin.

Nonessential amino acids can be produced by the liver. However, essential amino acids must be provided through the diet before any muscle can be synthesized. The correct ratios of essential and nonessential amino acids should be made available in sufficient quantities before any muscle can be produced.

Essential Amino Acids

Histidine	Methionine
Isoleucine	Phenylalanine
Leucine	Threonine
Valine	Tryptophan
Lysine	

Nonessential Amino Acids

Alanine	Glutamine
Arginine	Glycine
Asparagine	Proline
Aspartic acid	Serine
Cysteine	Tyrosine
Glutamic acid	

Nitrogen Balance

All the tissues in the body are composed of carbon, hydrogen, and oxygen. Only protein has the additional nitrogen molecule. Therefore, nitrogen excretion (meaning the amount of protein being eliminated from the body) can be measured to determine the amount of protein present in the body. Since 70% of protein is found in muscle tissue, nitrogen balance gives an excellent indication of the body's muscle-building potential.

There are three states of nitrogen balance:

1. *Positive:* This is the best situation for muscle growth. The protein (nitrogen) intake is greater than the nitrogen output. It shows that the body has sufficiently recovered from its last workout. The greater the nitrogen balance, the faster the workout recovery. This is the body's anabolic state.

2. *Negative:* This is the worst state an athlete can find himself or herself in. Nitrogen loss is greater than nitrogen intake. Not only is nitrogen drawn away from muscle, where it is needed for growth, but it is also taken from the vital organs, where serious damage can occur. A negative nitrogen balance also destroys muscle and is consequently considered a catabolic state. A negative nitrogen balance may result from consuming an insufficient amount of high–biological value proteins, poor-quality proteins (e.g., lunch meats, fatty meats, and vegetables), or protein sources lacking an optimal balance of the essential amino acids. A severe lack of protein equates to fewer antibodies to fight infection, and more frequent bacterial infections may be the result. To support protein synthesis, good-quality fats and carbohydrates should be available for energy purposes. If one consumes primarily protein, without considering the importance of other macronutrients, the body may metabolize the protein for energy purposes, thus lowering the nitrogen balance, in which case valuable amino acids will be shuttled to the vital organs, thus depriving the muscles of exactly what they need for growth. Training involves breaking down muscle tissue. Protein and rest help regenerate these tissues. Too much training, coupled with insufficient protein consumption, will hasten a negative nitrogen balance. In case of a negative nitrogen balance, all training should be

ceased, and protein intake should be increased significantly. If training is continued, the muscles might continue to deteriorate.

3. *Equilibrium:* This state should be what anyone might achieve at the very minimum. Nitrogen intake and loss are equal. The performance in this state is not regressing, nor are there any appreciable muscle gains.

Carbohydrate-Protein Mix

The postexercise ingestion of protein with carbohydrate accelerates recovery. In a recent study, a carbohydrate-protein combination maintained a positive nitrogen balance during and after a 6-hour endurance training session, while a straight carbohydrate drink did not.

The consensus of current scientific opinion is that following intense exercise, athletes should ingest a carbohydrate and protein mix (around 1 g of carbohydrate per kilogram of body mass and 0.5 g/kg of protein) within 30 minutes of completing exercise, as well as consuming a high-carbohydrate meal within 2 hours. This nutritional strategy accelerates glycogen synthesis and allows for a more anabolic situation that may hasten recovery.

Fat

The postworkout meal should be rich in protein and carbohydrate, but it should be fatfree. The consumption of essential fats is one of the most overlooked areas of daily nutritional intake. However, in the postevent situation, fat consumption can actually be counterproductive. Fat slows the transit of food through the intestines. Ingesting fat during the postworkout period may slow down the digestion and absorption of carbohydrates and proteins.

The postworkout meal should promote the fastest delivery of carbohydrates and protein to the depleted muscles, so fats should be avoided during this time.

Liquid Versus Complex

Liquid meals take better advantage of "the window of opportunity," where whole foods may miss this opportunity. Similar to the problems with a pre-event meal, eating a big meal can be difficult after an intense competition. Liquid supplemental formulas are palatable and easy to consume, and they can be quite nutrient dense, providing all the nutrition needed at this time.

Liquid supplemental formulas containing fast-digesting protein (whey hydrolysates and isolates) and carbohydrates (dextrose and maltodextrin) can be absorbed more quickly than whole-food meals. A liquid postexercise formula may be fully absorbed within 30 to 60 minutes, providing much-needed muscle nourishment during this time. However, a slower-digesting solid meal may take 2 to 3 hours to fully reach the muscle.

During the postexercise period, specific nutrients maximize recovery. These include an abundance of water, high-GI carbohydrates, and certain amino acids (in specific ratios). It is also best to avoid fat during this time. The only way to ensure that these nutrients are present in the correct amounts is to formulate a specific liquid blend. Whole foods may miss the mark.

Water

Fluid losses during an event can be calculated from the pre- and postevent weights. Athletes are encouraged to drink 16 oz of water for each pound lost. One half of the fluid loss should be replaced in the first 4 hours and the remaining half during the subsequent 8 hours. There is no one ideal postevent replacement fluid for all athletes.

Salt

Consider salt supplementation with 5 lb of weight loss or greater. Give 1 g of salt and 16 oz of fluid for each pound of weight loss over 5 lb.

Carbohydrate Loading

The "classic" regimen requires 3 days of intense, exhaustive exercise on an extremely low-carbohydrate (less than 10%), high-fat, high-protein diet to deplete the muscle glycogen stores. Days 4, 5, and 6 are spent resting and consuming a high-carbohydrate (greater than 80%) diet. The endurance event is held on Day 7, when the athlete consumes a normal, high-carbohydrate pre-event meal.

The "modified" carbohydrate regimen involves a moderate-carbohydrate (50%) diet on Days 1, 2, and 3 and a high-carbohydrate (>80%) diet on Days 4, 5, and 6. The endurance event is held on Day 7, when the athlete consumes a normal, high-carbohydrate pre-event meal as in the classic regimen.

Does this actually improve performance?

A 3-day, high-carbohydrate load (9 g kg^{-1} day^{-1} compared with 6 g kg^{-1} day^{-1}) increased muscle glycogen levels in cyclists, but there was *no* improvement in 100-km race time. Carbohydrate loading shows best results in runners with lower aerobic capacities in events lasting 1.5 to 2 hours.

Rest

Sufficient resting of the muscles following intense training is essential if protein synthesis is to take place. If training sessions are too frequent, even a protein surplus might be useless to fuel training efforts.

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See also Carbohydrates in the Athlete's Diet; Nutrition and Hydration; Protein in the Athlete's Diet

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Pregame Meal

The goals of pregame, or pre-event, meals are to ensure adequate carbohydrates, prevent dehydration, provide a relatively empty stomach, and avoid gastrointestinal disturbance and hunger pangs. The meal should be pleasant and satisfying, contain 60% to 70% carbohydrates, and be consumed 2 to 5 hours before competition. The meal before an endurance event should be individualized but should consist primarily of higher–glycemic index (GI) foods consumed 2 to 5 hours before exercise, with adequate fluid and electrolytes; shorter-duration events at higher intensity are less likely to be affected by the pre-event meal.

No last-minute food will make up for a poor diet in previous weeks. Supplements do not balance a poor diet. If an insufficient diet is supplemented, then you have an insufficient supplemented diet!

The Basics

Exercising muscles leads to burning of fat and glucose. Glucose is obtained from the glycogen stores in both the muscles and the liver and from the glucose circulating in the blood. The liver controls blood glucose levels to ensure that the blood sugar does not drop too low (causing weakness, dizziness, and nausea). If it detects low blood sugar levels, it can release glucose into the blood from its own glycogen store. Glycogen is the stored form of glucose in the body. If blood glucose levels rise (e.g., after eating food containing carbohydrates), insulin is released, which forces glucose out of the bloodstream and into storage.

The relevance of pre-exercise nutrition is as follows. During a fasting period (such as overnight), liver glycogen stores will be lowered. If the athlete competes in a morning event without having eaten anything since the night before, he or she is starting at a disadvantage. Although muscle glycogen will still start off high, once it is used up (after about 60 minutes), a limited amount of blood sugar supplied by the liver is available.

Glycemic Index

Some carbohydrates create a faster surge in blood glucose than other carbohydrates. A food's GI gives an indication of the expected degree of blood glucose.

High-GI foods (e.g., glucose, white bread, bananas) produce a substantial and immediate rush of glucose into the bloodstream. Low-GI foods (e.g., beans, lentils, full-grain products) release glucose at a slow and steady rate over a much longer time period. One potential problem with high-GI foods is that the high insulin response can actually lead to an increased storing of blood glucose, creating a net drop in blood sugar and its undesired effects.

For some time, a dogma that existed in sports nutrition was that sugar should not be consumed 60 to 15 minutes prior to exercise for fear of a hypoglycemic backlash. Several early studies found that the time to exhaustion was shorter, 20% to 25%, after athletes consumed 2 to 3 ounces (oz; 1 oz = 28.35 grams [g]) of glucose during the hour preceding an endurance event. More recent studies have failed to demonstrate this effect. Individual variability in athletes may explain the apparent contradictions in the current nutritional literature.

International studies have shown that large numbers of players eat foods that contain carbohydrates far below the optimal level of 2,400 to 3,000 calories (cal; 1 cal = 4.19 joules). As a result, athletes enter their competitions with insufficient glycogen levels. Players who start a match with low glycogen stores have few carbohydrates left in their muscles as the event progresses. This leads to poor performance, especially during the latter part of the competition. Glycogen-deficient athletes run sometimes as much as 50% slower during the latter part of events than in the earlier parts. Compared with competitors who have normal glycogen levels, low-glycogen athletes spend more time walking and less time sprinting as the competition proceeds.

Loading additional carbohydrates before an athletic event has a minimal effect if the event lasts less than 60 minutes. By analogy, adding an extra gallon of petrol to a car with a full tank before a short journey is not beneficial. However, if initial glycogen levels are low (e.g., when participating in a prolonged tournament) and/or the exercise lasts 90 minutes or longer, pre-exercise carbohydrate may improve performance.

Goals of a Pre-Event Meal

A good and balanced diet is as important for performance as proper training. Pre-event meals are a major factor. Before an athletic event or even before highly physical activities in general, certain aspects need to be considered. The meal before an event should ensure adequate carbohydrate intake, prevent dehydration, and avoid gastrointestinal upset. It should provide an empty stomach but prevent hunger pangs and should be pleasant and satisfying. The goal is to maximize the energy available to fuel the muscles and prevent hypoglycemia.

Timing

The timing of the pre-event meal determines whether the meal is helpful or counterproductive. In general, athletes have a meal 2 to 5 hours before the event. Liquid meals may be consumed up to 1 hour before the event. Fructose may be consumed until the time of the event with caution, because fructose-containing solutions are associated with gastrointestinal upset. High-GI carbohydrates taken immediately before high-intensity exercise may improve performance.

Hydration

Adequate fluid intake is paramount, especially when the event takes place in hot weather. Often, athletes hydrate 2 to 3 hours before practices, games, and events. Athletes should aim for at least 16 oz (2 cups) of fluid at this time. Generally, 10 to 30 minutes before competition, 250 to 1,000 milliliters (ml) of liquids should be ingested. A 2% loss of body weight from fluid deficit can impair endurance performance by 22%.

Food

An ideal pre-event meal should consist of 70% carbohydrates or more. It should produce only minimal bulk. The salt content depends on the athlete's cramping tendency (high crampers should use more salt). Experiments with new food before an event should be avoided. High-protein diets do not improve performance. Carbohydrate intake should be 1 to 4 g/kilogram (kg) body weight 1 to 4 hours prior to activity.

Sometimes, the pre-event time is marked with anxiety or excitement, which may preclude the intake of a regular meal. If the athlete cannot consume a solid meal because of anxiety or other causes, a liquid carbohydrate meal may be consumed up to

60 minutes before competition. A carbohydrate meal taken 3 hours before a running exercise at 70% $\dot{V}O_2max$ (peak oxygen uptake) increases insulin levels, but improved exercise time leads to exhaustion. Carbohydrate meals taken before and during high-intensity activity improved lap times, glucose levels, and insulin levels and decreased free fatty acid levels. A comparison between high- and low-GI pre-exercise meals showed no difference in endurance time; however, the low-GI meal resulted in increased fat metabolism. Pre-exercise high-GI foods decreased blood sugar levels, but they had no effect on 10-kilometer (km) running time. Low-GI foods consumed within 1 hour before endurance competition may provide carbohydrates without an associated insulin surge but are associated with a feeling of fullness.

High-fat (61% of calories) meals increased fat oxidation and decreased carbohydrate oxidation but did not change endurance cycling time compared with low-fat (31% of calories) meals. Extra fluid or electrolyte solutions, which may guard against dehydration, hyponatremia, and hyperthermia, may be consumed as tolerated up to the time of the event.

Alcohol

Consumption of alcohol adversely affects the performance of athletes. Five or more alcoholic beverages in one night can affect brain and body activity for up to 3 days. Two consecutive nights of five or more drinks can affect the athlete for up to 5 days. What many athletes do not realize is that five drinks each on Friday and Saturday nights will affect Thursday's performance. A hangover reduces performance by 11%. Alcohol also influences fluid homeostasis. Within 4 hours of drinking alcohol, there is an increased loss of urine. Fluid losses can reach 3% of body weight, but there is already a significant drop in performance when fluid losses reach 2% of body weight.

Salt

Cramping can be devastating to an athlete's performance. Frequently, the cramping is due to high salt losses from sweating. Athletes should salt their food to replace the sodium they lose during sweating, especially if they are heavy crampers. Athletes have varying degrees of salt concentration in their sweat. Those with high salt concentrations may need more salt than the average sweating athlete.

Carbohydrate Loading

Athletes are constantly looking for an "edge" to gain an advantage. Carbohydrate loading is a dietary technique that has been used for quite some time.

Carbohydrate loading (also known as glycogen supercompensation) may improve performance in endurance competition by allowing the muscles to store two to three times more glycogen than normal.

The "classic" regimen requires 3 days of intense, exhaustive exercise on an extremely low-carbohydrate (<10%), high-fat, high-protein diet, to deplete the muscle glycogen stores. Days 4, 5, and 6 are spent resting and consuming a high-carbohydrate (greater than 80%) diet. The endurance event is held on Day 7, when the athlete consumes a normal, high-carbohydrate pre-event meal.

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Does this actually improve performance?

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See also Carbohydrates in the Athlete's Diet; Protein in the Athlete's Diet

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Preparticipation Cardiovascular Screening

The preparticipation physical exam (PPE) is a well-entrenched part of our sports culture. The purpose of this exam is to review the general health of athletes and make sure that it is safe for them to participate in organized sports. At this point, approximately 30 to 40 million athletes participate in organized sports each year.

Sports-associated sudden cardiac death (SCD) is defined as the death of an athlete from cardiovascular causes during or within 1 hour of completing a sports activity. The death of an athlete, often regarded as a model of physical fitness, is a devastating loss to both the family and the community in which the athlete lives. Many athletes who have experienced such an outcome were considered to have been previously asymptomatic; for this reason, an ongoing debate has arisen regarding screening methods to detect the potentially lethal disorders that lead to SCD in athletes.

Any of a variety of disorders may result in the death of an athlete. For athletes younger than 35 years of age, undetected coronary artery disease is the most common cause, and there are a variety of congenital causes that are thought to contribute to this adverse outcome.

The most common cause of SCD is hypertrophic cardiomyopathy (HCM), which accounts for approximately 40% of deaths in the United States. This disease may have prevalence as high as 1 out of 500 individuals. This disorder results in asymmetric hypertrophy of the intraventricular septum of the heart, which may result in obstruction of blood flow at near-maximum levels of exercise. Also, this hypertrophy and potential obstruction may cause the initiation of an arrhythmia, which then leads to a failure of the electrical conduction system of the heart.

Abnormal development of the coronary arteries, otherwise known as anomalous coronary arteries, is also a common cause of SCD. Typically, during embryogenic development, the coronary arteries arise from and are located in the center of the left and right anterior sinuses of the aortic valve. However, in some individuals, these arteries arise in another fashion. There are multiple variations of this anomalous origin, which is beyond the review of this entry. Of particular interest in SCD is the origin of the left coronary artery from the right sinus of Valsalva, where the right coronary artery also arises. In this instance, the left coronary artery then courses between the aorta and the pulmonary artery, where during periods of intense activity, this artery may become obstructed, resulting in decreased blood flow to a significant portion of the heart, leading to ischemia and cardiac death.

Another common cause of SCD is arrhythmogenic right ventricular dysphasia (ARVD), which is also sometimes referred to as arrhythmogenic right ventricular cardiomyopathy (ARVC). This disorder is thought to result in abnormal growth and development of the myocytes of the heart, leading to myocyte disarray; this disarray also leads to the development of a fibrous fatty deposit that develops in the myocardium. It is thought that this fibrous tissue may lead to the development of an arrhythmia, which could often prove to be fatal.

There are multiple other cardiac abnormalities that may result in SCD, including, but not limited to, the following: myocarditis, severe mitral valve prolapse, long QT syndrome, Brugada syndrome, Marfan syndrome, and sarcoidosis.

Any effective screening test to look for cardiovascular abnormalities such as those noted above should have several key characteristics. It should be able to detect such abnormalities with an appropriate level of sensitivity. This allows for identification of those athletes with the abnormalities that may result in SCD (the true positives). It should also have a high specificity, which would mean that those who test negative truly do not have the disease (true negatives). It would be preferable for the screening tests to approach both 100% sensitivity and 100% specificity in order to prevent a large number of false-positive and false-negative results. In actuality, no test truly reaches such percentages, but the best tests do have values upward of 90% for both specificity and sensitivity. In addition, the test should be able to accurately predict all causes of SCD. Finally, there should be a set point in the course of athletics when the test should be offered to effectively screen everyone while avoiding duplication of services. The following section examines several cardiovascular screening methods that could be used at present.

Cardiovascular Screening Methods

The most commonly touted method of cardiovascular screening is the electrocardiogram, commonly known as the EKG. This test measures the electrical activity of the heart through the use of electrodes spread across the body. The placement of the electrodes and the resulting electrical potentials measured by such electrodes result in a "tracing" of the heart's electrical activity. Several of the diagnoses discussed above may result in abnormal electrical tracings (i.e., evidence of left ventricular hypertrophy and inverted T waves in the percordial leads in HCM). However, even for HCM, EKG sensitivity may only be as high as 50%, with at least a 4% false-negative rate. This is due, in part, to the normal physiologic changes that develop with participation in athletics, known as the "athletic heart"; many of these changes may mimic cardiac abnormalities and will often lead to further, often unnecessary, testing. Additionally, several of the diagnoses associated with SCD will have no electrocardiographic abnormalities even in the best of circumstances (e.g., anomalous coronary arteries).

Another test that could be used is the echocardiogram, which uses ultrasound waves to form an image of the heart. This would be beneficial in looking for abnormalities such as asymmetric septal hypertrophy, which may be noted in conditions such as HCM. The use of echocardiography also allows for visualization of the origin of both coronary arteries. However, this test is much more expensive than electrocardiography, is more time intensive, and requires specialized training to administer and to interpret.

At present, it is recommended that athletes have brachial blood pressures recorded, with auscultation of the heart in both supine and standing positions, along with palpation of the radial and femoral pulses for the cardiovascular exam of the PPE. There has also been some consideration given to providing a more thorough history and physical examination during the PPE to screen for cardiovascular abnormalities. This concern has been raised by several studies that have demonstrated that perhaps several of the athletes who had SCD may have indeed exhibited symptoms such as syncope, chest pain, or dyspnea on exertion prior to succumbing to SCD. The PPE portion requires special attention to be given to the cardiovascular screening questions often present on the PPE form, and the physical examination includes provocative maneuvers such as a Valsalva maneuver to try to elicit findings, such as a murmur, that otherwise may not be appreciated. This would not require any further equipment besides that currently employed at PPE screening; it would, however, require education of those performing PPEs as well as the probable formation of standardized guidelines beyond those currently available. However, to date no published studies have concluded that screenings such as these are any more accurate than the traditional PPE.

There are other tests that, in the future, may become applicable to cardiovascular screening. These could include imaging studies (coronary CT [computed tomography] or cardiac MRI [magnetic resonance imaging]), or they may be perturbations of currently accepted techniques (two-lead EKGs, a handheld limited echocardiogram). At present, these technologies are either too limited in availability or still considered experimental.

Other countries do require some form of screening for cardiovascular abnormalities prior to athletic participation. In Italy, for example, a screening EKG is required as part of the PPE process. A review of the data of the past 20 years reveals a decrease in the rate of SCD in Italy. However, at this time, the current rate of SCD is equal to the best estimate of the currently observed rate found in the United States, along with a disqualification rate that would probably not be acceptable in the United States. Also, there appears to be a dominance of ARVC as a cause of SCD in

Italy, probably secondary to genetic differences in the population of each country. Finally, the cost of EKG is much cheaper in Italy (approximately equal to US$10), and the country itself is much smaller, with fewer athletes than in the United States. Based in part on the evidence from Italy, the International Olympic Committee now requires screening EKGs in all its athletes prior to Olympic competition. Also, partly in response to recent SCD events in its athletes, the National Basketball Association now requires screening electrocardiograms (EKGs) on all its rookie athletes prior to competition. In both these instances, however, there are a much smaller number of athletes competing at much higher levels of competition and/or compensation when compared with the rest of the athletic population as a whole.

Finally, the costs of mandatory cardiovascular screening must be factored in as well. At present, EKG screening seems to be the most commonly considered and, if screening were to be employed, the most practical as well as the most cost-effective. However, even when using a conservative estimate of $30 per EKG as well as a screening of only 10% of the athletic population per year, this would result in a cost to the U.S. health care system of $90 million/year.

Conclusion

In summary, there is still considerable debate regarding preparticipation cardiovascular screening. Given the current limitations in testing abilities and in the availability of screening, as well as the cost-prohibitive nature of such screening, the application of such screening will continue to be limited to specific populations; however, there will continue to be research and discussion on the best methods with which to conduct such screening so as to attempt to eliminate SCD in the young athlete.

Daniel S. Lewis

See also Physical Examination and History; Presports Physical Examination

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Presports Physical Examination

When we look at the preparticipation physical exam (PPE) in sports, we see that the overall objective is to promote the health and safety of the athlete in training and competition. This can be divided further into several basic objectives:

1. To determine the general health of the athlete
2. To detect any conditions that might limit participation, such as hypertrophic cardiomyopathy or aortic stenosis, or any catastrophic event that may place the athlete at risk
3. To detect conditions that might predispose the athlete to injury, such as illness or injuries, lack of conditioning or flexibility, overuse injuries, inadequately rehabilitated injuries, and congenital or developmental problems
4. To evaluate the fitness level of the athlete, and perhaps to improve performance and prevent injury
5. To afford an opportunity for physician-athlete discussion regarding adolescent health care and issues such as testicular and breast self-examination, drug use, alcohol, smoking,

smokeless tobacco, obesity, safe sexual practices, use of seat belts, disordered eating, and nutrition (a correlation between athletes and "risk-taking" behaviors has been reported)

6. To meet legal and insurance requirements

Consistency, Timing, and Frequency of Examination

Minimum requirements for the preparticipation athletic screening are published and clearly outlined but may vary widely in content, length, and comprehensiveness. A licensed practitioner who has the medical skills, background, and training to take the recommended history and physical examination should perform the examination.

Six weeks prior to the season would be an ideal time for the PPE, as this would allow for correction and/or rehabilitation of problems prior to activity. However, the timing of the examination will ultimately depend on the resources of the community, the schools, and the patients. It is recommended that high school athletes get a complete PPE (a) every 2 years with an interim history in the intervening years, (b) when transitioning from junior high school to senior high school, and (c) if switching from one school to another. College student-athletes should undergo a complete PPE initially on entry to college, with a limited annual history afterward that addresses vital signs and any significant changes that may constitute evidence that another examination and further testing are warranted. Many schools require PPE examinations more often than recommended based on local and state requirements.

Type of Examination

PPEs can be accomplished by office-based evaluations or mass-screening, "station" evaluations. Primary care office-based PPEs have the advantages of (a) physician-patient familiarity, (b) continuity of care, and (c) an opportunity for counseling, while the disadvantages include (a) many athletes not having a primary care physician, (b) limited time for appointments, (c) varying knowledge and interest in sports medicine problems, (d) greater cost, and (e) lack of communication with the school athletic staff. Station-type mass examinations have the advantages of (a) specialized personnel, (b) being efficient and cost-effective, (c) good communication with the school athletic staff, and (d) the opportunity for performance testing, while the disadvantages include (a) a noisy environment, (b) lack of privacy, (c) difficulty following up on medical problems and concerns, and (d) lack of communication with parents. It should be recognized that the type of physical examination provided to the athletes may vary according to the needs of the athletes and the resources of the community. If not performed by one's family practitioner, the PPE is meant as a screening tool only and should not be considered to take the place of a comprehensive health maintenance visit.

Athletes should be provided in advance with information about the detailed nature of the examination and the appropriate attire to wear so as to deal with privacy concerns and increase efficiency. Male and female athletes should have separate examination areas. Private individual counseling should be available for discussion of sensitive issues to maintain confidentiality and facilitate better communication. A clear protocol should be established for referral and rehabilitation if needed. Athletes from low-income families may need assistance in arranging and completing follow-up evaluations. If the athlete is not cleared for the desired sport, the evaluating physician should counsel the athlete concerning alternate permissible activities.

History

The medical history is the cornerstone of this evaluation. A complete history will identify most problems affecting the athletes. The history should focus primarily on the cardiovascular, musculoskeletal, and neurological systems, as well as questions regarding general health. A standard PPE form should be used that is brief, easy to read, and understandable by athletes and parents and that allows adequate space for elaboration of positive findings. A copy of a standard PPE form that follows national guidelines in content and structure can be found at http://www.newamssm.org/ppe history.pdf and may be reproduced as needed.

Personal and family histories reveal approximately 75% of the conditions that may prohibit or alter sports participation; therefore, the history is a more sensitive screening tool than the physical examination. Parents and athletes should fill out the form together, and signed parental consent for emergency treatment should be obtained. Reported histories filled out by athletes often do not agree with the information provided by parents, so parental verification of history is recommended.

- Has your doctor ever denied or restricted your participation in sports for any reason?
- Do you have any medical conditions (e.g., asthma, heart disease, or diabetes)?
- Have you ever spent a night in a hospital?
- Have you ever had surgery?

You may discover information regarding past or recent hospitalizations that may affect participation. You may also determine whether a medical illness is under proper control. Frequent admissions for asthma, seizures, and diabetes may require better control before athletic clearance. A history of recent surgery may necessitate a more directed examination to ensure adequate healing time and recovery.

- Are you currently taking any prescription or nonprescription (over-the-counter) medications or pills?

Knowledge of the prescription and over-the-counter medications that athletes take is important. Intermittent medications such as inhalers and antihistamines may affect performance. The proper use of the inhaler should be discussed. The use of nutritional supplements and/or oral contraceptives should be noted. Finally, any history of illicit drug use, such as steroids, cigarettes, marijuana, cocaine, alcohol, smokeless tobacco, or human growth hormone, should be discussed if appropriate. Insulin-dependent diabetics are predisposed to hypoglycemia, and injection sites may need to differ with each sport. Because exercise enhances absorption of insulin from the injection site, nonexercised injection sites should be used. Some athletes do better on a more frequent insulin injection schedule with glucose monitoring while in competition. With diabetes, exercise should preferably be done after meals and daily rather than occasionally and sporadically. Exercise will enable the youth to adjust his or her dietary and insulin requirements, as physical activity appears to increase an individual's sensitivity or responsiveness to insulin. The use of insulin pumps and contact sports should be discussed.

- Do you have any allergies to medicines, pollens, foods, or stinging insects?

A history of allergy to medicines, foods, and insects may necessitate prescription epinephrine kits on the sidelines. Seasonal allergies may be clues to chronic use of over-the-counter drugs. A history of exercise-induced anaphylaxis may necessitate prophylactic antihistamines.

- Have you ever passed out during or after exercise?
- Have you ever had discomfort, pain, or pressure in your chest during exercise?
- Has a doctor ever told you that you have high blood pressure, high cholesterol, heart murmur, or a heart infection?
- Does your heart race or skip beats during exercise?
- Has a doctor ever ordered a test for your heart, that is, EKG or echocardiogram?
- Has anyone in your family died for no apparent reason?
- Does anyone in your family have a heart problem?
- Has any family member or relative died of heart problems or of sudden death before 50 years of age?

Because the majority of sudden death cases in athletes under 35 years of age involve the cardiovascular system, careful attention to cardiac history is paramount. Certain symptoms can identify at-risk individuals with underlying cardiac abnormalities. Strict guidelines have been published regarding the cardiovascular preparticipation screening of athletes. The most common cause of sudden death in young athletes in the United States remains hypertrophic cardiomyopathy. Syncope and near-syncope are "red flags" that should make you consider hypertrophic cardiomyopathy, conduction abnormalities, valvular problems, or congenital coronary artery abnormalities. Advanced atherosclerosis is a rare cause of coronary artery disease in the younger age-group, unless it is associated with a lipid abnormality, but it may be a factor in the older athlete. Congenital abnormality of the coronary arteries (the absence or underdevelopment of coronary arteries; anomalous artery) may be a cause of chest pain and sudden death, but it is difficult to identify without invasive testing.

The medical history should address prior heart murmurs, rheumatic fever, or cardiac surgery. Approximately one third of all adolescents will have audible murmurs, and if these are considered to be normal and functional, the athlete should be reassured that there is no problem. Otherwise, further workup or referral to a cardiologist is recommended. Although no studies are available documenting the prevalence of mitral valve prolapse (MVP) in athletes, screening tests of apparently healthy women have revealed that approximately 5% have auscultatory or echocardiographic evidence of MVP. Sudden death has rarely been associated with MVP, and its finding in the absence of any serious symptomatic ventricular arrhythmias or other symptoms should be considered benign. A more conservative approach should be followed for the occasional athlete with MVP and other symptoms or arrhythmias. Any history of recent severe viral infection that may indicate a risk of myocarditis should be investigated. Palpitations may suggest Wolfe-Parkinson-White syndrome, Lown-Ganong-Levine syndrome, arrhythmias, and other conduction abnormalities. Paroxysmal supraventricular tachycardia is not a reason for restriction from full, competitive participation if the arrhythmia can be controlled; an exercise EKG should be obtained to observe what happens to the cardiac rhythm during intense activity. When in doubt, consult a cardiologist! A family history of sudden death should alert you to some of the common hereditary causes of sudden death. Hypertrophic cardiomyopathy, Marfan syndrome, and some of the prolonged QT syndromes are autosomal dominant (transmission of Romano-Ward syndrome [no deafness] is autosomal-dominant; transmission of Jervell and Lange-Neilson syndrome [QT prolongation, (+) deafness] is autosomal-recessive). EKG changes may be manifested only after exercise. These are rare diseases; however, the risk of sudden death in these patients may be as high as 1% per year. A family history of hypercholesterolemia should also be discussed.

The sensitivity of tests detecting diseases leading to sudden death increases in proportion to the financial resources that can be applied to the screening program. Although at times debated in the literature, the relative high cost of screening and low yield of a positive test in this relatively healthy population of athletes make mandatory noninvasive screening procedures unfeasible. The routine use of EKG has not been demonstrated to effectively enhance the present screening guidelines and is not presently recommended as a routine screening tool for PPE. EKG, echocardiogram, and exercise stress testing are indicated only when findings on history and physical examination warrant further testing. Cardiac consultation should be sought in cases of indecision.

- Does anyone in your family have Marfan syndrome?

Marfan syndrome is an autosomal-dominant disorder caused by a defective gene for the production of fibrillin. Athletes with Marfan syndrome are at risk for cystic medial necrosis with resultant aortic dissection and cardiac valve malformations. Physical stigmata of Marfan syndrome include kyphosis, a high-arched palate, pectus excavatum, arachnodactyly, arm span greater than height, MVP, aortic insufficiency, myopia, lenticular dislocation, “thumb sign,” and “wrist sign.”

- Do you tire more quickly than your friends during exercise?

Dyspnea on exertion could signify chronic lung disease, reactive airway disease, or valvular disease.

- Have you ever had an injury, such as a sprain, muscle or ligament tear, or tendinitis that caused you to miss a practice or game?
- Have you had any broken or fractured bones or dislocated joints?
- Have you had a bone or joint injury that required X-rays, magnetic resonance imaging (MRI), computed tomography (CT), surgery, injection, rehabilitation, physical therapy, a cast, or crutches?

Orthopedic review of systems is obviously important. Focus on any history of injuries to bones, joints, and muscles. Previous history of fractures, dislocations, subluxations, sprains, strains, and tendinitis should be discussed, as well as a review of treatments and rehabilitation modalities that have occurred.

- Have you ever had a stress fracture?

Repetitive stress, poor training technique, menstrual irregularity, poor dietary intake, and/or disordered eating patterns may predispose the athlete to stress fractures.

- Do you regularly use a brace, assistive device, or any special equipment?

Document any pads, braces, neck rolls, sleeves, mouthguards, eye guards, athletic supportive cups, and so on that are used by the athlete during activity.

- Have you ever been told that you have asthma or allergies?
- Do you cough, wheeze, or have difficulty breathing during or after activity?
- Is there anyone in your family who has asthma?
- Have you ever used an inhaler or taken asthma medications?

Athletes with asthma and/or exercise-induced bronchospasm (EIB) should be identified. Find out what treatments have been used in the past and how successful those treatments have been. Remember, EIB is often undiagnosed, and some patients may have only a cough as their asthma variant. The examiner should inquire about difficulty in breathing or wheezing during or after exercise, cough, easy fatigability, chest pain, or tightness in the chest. Make sure that those on inhalers are using them correctly, and consider inhaler spacer devices when appropriate. Children with asthma and EIB should not be restricted but rather encouraged to participate in a full range of exercise activities. Those athletes who are resistant to a challenge of bronchodilators may be followed with pulmonary function studies and/or pulmonary consultation.

- Were you born without or do you have a missing kidney, an eye, a testicle, or any other organ?

Certain restrictions and protective wear may be required for competition.

- Have you had infectious mononucleosis (mono) within the last 3 months?

Full clearance after a bout of infectious mononucleosis is required before activity.

- Do you have any rashes, pressure sores, or other skin problems?
- Have you had a herpes skin infection?

Review of the athlete's dermatological history may reveal sexually transmitted diseases, herpes simplex, scabies, pubic lice, molluscum contagiosum, furunculosis, carbunculosis, and impetigo. A history of itching skin and/or acne should also be reviewed, as equipment and perspiration may exacerbate skin conditions.

- Have you ever had a head injury or concussion?
- Have you ever been hit in the head and been confused or lost your memory?

The number of previous concussions is an important factor when determining preparticipation clearance. Even more important is whether each of those previous concussions resolved completely before return to play. The use of preparticipation neuropsychological testing may be of benefit in some cases.

- Have you ever had a seizure?
- Do you have headaches with activity?

The guidelines regarding epilepsy and participation must be individualized; in athletes with poorly controlled seizures, clearance should be deferred until therapeutic drug levels are reached, the neurological examination becomes normal, and a 1-month seizure-free interval is achieved. Skiing, scuba diving, rope and rock climbing, gymnastics on the high apparatus, parachuting, hang gliding, horseback riding, and high diving are contraindicated in athletes with a history of uncontrolled seizures. Athletes with well-controlled seizures can be cleared to participate in contact and collision sports, provided these activities do not precipitate the seizure activity. Relative contraindicated sports include swimming without the presence of a person qualified in lifesaving techniques, weight lifting, javelin, shot put, discus, archery, and shooting sports such as pistol and rifle shooting.

- Have you ever had a stinger or burner or pinched nerve?
- Have you ever had numbness, tingling, or weakness in your arms or legs after being hit or falling?
- Have you ever been unable to move your arms or legs after being hit or falling?

A thorough review of the athlete's history of any neurological conditions or injuries is required. Burners/stingers and pinched nerves are traumatic neuropraxias secondary to pinching or stretching of the cervical nerve roots or brachial plexus. Signs and symptoms include numbness and tingling in the upper extremity, with occasional weakness in the *absence* of neck pain or stiffness. Burners/stingers do not preclude participation if no neck pain or radicular pain is present, the cervical spine has full range of motion, and no preexisting cervical spine abnoorities and evidence of permanent neurological damage are present (cervical spine instability or degenerative changes). Athletes with a history of recurrent burners/stingers should be counseled regarding neck and upper extremity strengthening, proper technique, and use of protective equipment (neck roll, proper shoulder pad fit). Cervical spinal cord neuropraxia with transient quadriplegia is a rare entity and may occur as a result of trauma. It is found in individuals with cervical spinal stenosis, congenital fusions, cervical instability, and intervertebral disk protrusions. It may also occur in individuals without predisposing abnormalities. Symptoms manifest themselves as burning pain, numbness or tingling, and weakness or paralysis of all four extremities. Episodes are transient, and recovery is usually complete within 10 to 15 minutes, although some cases gradually resolve over 36 to 48 hours. There is no evidence that transient quadriplegia predisposes an athlete to permanent neurological injury, but further consultation is necessary to evaluate the athlete for other underlying cervical spine abnormalities; these patients should be treated on an individual basis, with clearance from a neurosurgeon before return to activity.

- When exercising in the heat, do you have severe muscle cramps or become ill?

Review of an athlete's history of heat-related disorders is important, especially for those training or competing in hot or humid environments. Because athletes with previous heat issues are at increased risk for recurrence, any history of problems with activity in the heat should be documented. Extrinsic factors related to heat illness may include the sporting activity, the environment, geography, clothing and equipment, and certain medications and supplements; intrinsic factors may include dehydration, previous history of heat illness, inadequate acclimatization, poor aerobic fitness, excess body fat, large body size, fever, overexertion, and younger age. Athletes with this condition are usually allowed to participate, but temperature extremes must be avoided and hydration maintained throughout training.

- Has a doctor told you that you or someone in your family has sickle cell trait or sickle cell disease?

Athletes with sickle cell trait are at increased risk of complication when exposed to extreme environmental conditions, such as physical exertion at high altitude or at high temperatures. These athletes should be counseled on appropriate hydration and acclimatization to reduce risks.

- Do you have any problems with your eyes or vision?
- Do you wear glasses, contact lenses, or protective eye wear?

The examiner is specifically looking for the athlete who is single eyed due to complete blindness or has best-corrected vision poorer than 20/40 in one eye. Document what type of contact lens the athlete uses. Obtain any history of previous eye injury or surgery. In those with best-corrected vision poorer than 20/40 in one eye, protective eye gear approved by the American Society for Testing and Materials is required for competition if eye trauma is a possibility. For the one-eyed athlete, sports in which no eye protection can be worn are contraindicated. A detached retina requires clearance by an ophthalmologist. High-risk sports include sports with hard projectiles, sticks, and close contact, such as baseball/softball, basketball, cricket, fencing, field and ice hockey, lacrosse, racquetball, and squash. Sports that put the eyes at risk also include boxing, martial arts, and sports with small, fast projectiles, such as paintball.

- Are you satisfied with your eating patterns?
- Are you unhappy with your weight, trying to gain or lose weight?
- Has anyone recommended you to change your weight or eating habits?
- Do you limit or carefully control what you eat?

Screening for disordered eating patterns is recommended.

- Have you ever had a menstrual period? What was the age of your first period?
- Are your periods regular? How many periods have you had in the past 12 months?
- Have you missed any periods? Any chance that you might be pregnant?

Female athletes should be aware of the importance of a normal menstrual cycle during training. Consideration for estrogen replacement may be appropriate in these athletes. No restrictions are necessary for women with one ovary. Gender-specific aspects of the PPE have been discussed.

- Do you have any concerns that you would like to discuss with a doctor?

This question gives the athlete a chance to discuss issues of interest or concern in private.

Physical Examination

The physical examination can be relatively brief and can focus on areas that are more pertinent to safe participation, particularly the cardiovascular, pulmonary, and musculoskeletal examinations. More detailed examination may be warranted if suggested by the history given previously. The examination should be performed with awareness of the requirements of the particular sport(s) being played by the athlete in question.

Athletes should dress properly for the examination. Height, weight, and body mass index (BMI) are documented and compared with standard growth curves when growth abnormalities are suspected. Thinness may be suggestive of eating disorders, while large increases in body mass over a short period may suggest steroid use. Body fat composition may be required for gymnastics and wrestling. Extremes of thinness and obesity should be addressed.

Blood pressure, heart rate, and respiratory rate should be documented. Although blood pressure measurement is rarely an indication for disqualification from sports, abnormalities are often first noted during the sports physical examination. Hypertension in the adolescent can be a marker of endocrinologic, renal, cardiac, or central nervous system abnormalities or substance abuse. Blood pressure should be compared with age-adjusted tables, as well as interpreted on the basis of the person's gender and height. Standards have been developed by the Task Force on Blood Pressure Control in Children; National Heart, Lung, and Blood Institute; and National Institutes of Health. Proper-sized sphygmomanometer bladder cuffs should be used on all patients. Athletes with blood pressure changes can be referred for follow-up care with a primary care provider. Certain sports, such as weight lifting, may cause significant blood pressure elevations. If hypertension is identified on serial readings, exercise stress testing to determine blood pressure response to maximum exercise may be recommended as part of the workup prior to clearance. Despite recommendations, no findings have been published regarding morbidity/mortality attributable to hypertension in the student athlete, and a relatively liberal position has been taken in allowing participation. In these patients, recommendations of reduction in weight, moderate use of salt in foods, and aerobic exercise are prudent. A history of caffeine, nicotine, or supplements such as ephedra should be elicited.

The oral cavity, ears, nose, and throat should be examined. An eye examination (papillary exam, visual acuity) should be performed. Visual acuity, measured with a Snellen eye chart, should be correctable to better than 20/50. In those with best-corrected vision poorer than 20/40 in either eye, protective eye gear approved by the American Society for Testing and Materials is required for competition. Screening for baseline anisocoria should be done. Use of glasses or contacts, as well as use of approved protective eye wear, needs to be documented. Scar formation or perforation of the tympanic membrane (TM), septal nasal deviation or polyps, oral ulcers, gingival atrophy, enamel erosion, leukoplakia, a high-arched palate, braces, and lymph node enlargement also need to be documented. Poor dentition may be a sign of an eating disorder.

Heart and lung examination should be performed. Document symmetric diaphragmatic excursion, clear breath sounds (no rales, wheezing, rubs), and the absence or stability of any asthma or chronic lung disease. Remember that a normal lung examination does not preclude the possibility of exercise-induced bronchospasm. Palpation of peripheral pulses (radial and femoral simultaneously) may pick up a previously missed coarctation of the aorta. Cardiac auscultation with provocative maneuvers can differentiate a benign, innocent heart murmur from a pathological murmur. Auscultate the chest with the athlete supine and standing, and using the Valsalva maneuver, and listen for murmurs. Be familiar with the murmur of hypertrophic cardiomyopathy (increases with standing, the Valsalva maneuver). The murmur of hypertrophic cardiomyopathy is not sensitive but very specific. Unifocal ectopic beats of atrial or ventricular origin have been considered benign and of little risk to the young athlete if they are fewer than 6 to 8 per minute and decrease with low-intensity exercise (10 sit-ups or deep knee bends). Youths who are symptomatic or in whom ectopic beats do not disappear, or in whom there is an increase in premature ventricular contractions (PVCs) at low intensity, should undergo exercise electrocardiography. If the PVCs disappear when the cardiac rate reaches 140 to 150 beats/minute, the ectopic beats are likely to be benign and do not preclude full competitive activity (monitor the EKG for 10 minutes postexercise to observe malignant arrhythmias during the recovery period). Frequent sporadic ectopic beats of fixed coupling may rarely be associated with myocarditis.

Check the abdominal exam for masses, tenderness, and organomegaly. An athlete with hepatomegaly or splenomegaly should be disqualified and referred for evaluation. The male genital examination should rule out testicular pathology; document a single or undescended testicle, testicular mass, hernia, and varicoceles. Instruct the athlete on the proper technique for the self-testicular examination. The female genital and breast examination is not usually a basic part of the preparticipation examination, but any athlete with menstrual irregularities or breast complaints requires referral. Those in need of a Pap test as per the guidelines of the American Academy of Family Practice should also be referred or rescheduled.

Skin rashes, lesions, and tattoos should be documented. Any dermatological conditions, such as acne, rashes, or skin infections (furuncle, carbuncle, herpes, scabies, lice, molluscum contagiosum) should be treated. Any suspicious nevi or lesions should be excised for identification. Increased acne on the back may be a sign of steroid use. Some athletes may attempt to hide skin conditions that may limit their clearance, so be sure to have the athlete wearing appropriate clothing that will allow for skin visualization. Also, make a point to examine any lesions that are covered with adhesive strips (such as Band-Aids) or bandages at the time of examination.

A neurologic examination should be performed only if the musculoskeletal examination is abnormal, the history is suggestive of a neurologic condition, or the patient has a history of concussions with symptoms.

A standard screening musculoskeletal examination is performed, looking at the contour, range of motion, stability, and symmetry of the neck, back, shoulder/arm, elbow/forearm, wrist/hand, knee, leg/ankle, and foot. A more detailed examination should be undertaken if indicated by the history and physical exam. The following maneuvers should be performed:

- Inspection
- Forward flexion, extension, and lateral flexion of the neck
- Resisted shoulder shrug
- Internal and external rotation of the shoulders
- Resisted shoulder abduction
- Extension and flexion of the elbows
- Fist clench and finger spread
- Back flexion and extension

- Standing/walking on toes and heels
- Duck walk

Special Olympics

Physically challenged athletes can often safely enjoy the thrill of competition. Because physically challenged athletes are many times more likely than most athletes to have a sport-specific impediment, preparticipation examinations must be tailored to meet their special needs. In Down syndrome, the incidence of atlantoaxial instability is 10% to 20%; therefore, all athletes who have Down syndrome should have initial cervical spine radiographs taken to rule out atlantoaxial instability as part of the preparticipation examination. If atlantoaxial subluxation or dislocation and neurologic signs or symptoms are present, all strenuous activities are contraindicated. The athlete should not participate in any contact/collision or limited contact/impact sports, or sports that place undue repetitive flexion or extension stress on the cervical spine, such as butterfly stroke and breaststroke in swimming.

Clearance for Participation

When considering clearance for participation in a particular sport or activity, the practitioner must understand the demands of the sport to evaluate and make recommendations. Does the problem place the athlete at increased risk of injury? Are any other athletes at risk due to the problem? Can the athlete safely participate with treatment (medications, rehabilitation, bracing)? Is limited participation allowed during treatment? If clearance is denied, what limited activities can the athlete safely participate in? After the PPE, the athlete is typically assigned into one of three categories: (1) cleared to play with no restrictions; (2) cleared to play following further evaluation, treatment, rehabilitation, or documentation; and (3) not cleared to play certain types of sports. Lists of conditions that can limit participation and recommendations on who can and cannot compete are available.

In general, it is rare that athletes are not eventually cleared. One study showed that the majority of PPE disqualifications involved the following seven findings: (1) dizziness with exercise, (2) asthma, (3) unfavorable BMI, (4) blood pressure, (5) visual acuity defect, (6) heart murmurs, and (7) musculoskeletal abnormality. Many of these conditions were further evaluated and deemed low risk, and clearance was eventually granted.

The role of the preparticipation sports examination is not to exclude from participation but to make athletics safer for participants. For a screening tool to be effective, it should identify the conditions that will affect the athlete, be both sensitive and accurate, and be practical and affordable. The practice of providing preparticipation medical screening for athletes is neither supported nor refuted by the current medical literature, but while acknowledging these concerns, an organized academic approach to this examination, when thoroughly and consistently performed and supervised by qualified licensed providers, can be an effective tool in identifying medical and orthopedic conditions that may affect the athlete's ability to safely participate in sports.

Kevin N. Waninger

See also Physical Examination and History; Running a Sports Medicine Practice; Team Physician; Young Athlete

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Pressure Injuries to the Skin

There are several dermatologic entities that are a result of trauma, specifically of friction and pressure during athletic activities. Blisters are a common acute friction injury, and they are seen in almost all athletes. Blisters form when an intraepidermal split occurs from a shearing force within the level of the stratum spinosum (see Figure 1). The stratum spinosum is the deepest layer of the epidermis before the dermis and contains the rete pegs and hair follicles. The split that occurs in blisters rapidly fills with fluid, the composition of which is similar to plasma but with a lower protein content. They may also fill with blood, creating a hemorrhagic or "blood" blister. Blisters typically occur on the hands and feet. On the feet, most commonly, blisters affect the tips of the toes, the balls of the feet, and the back of heels. Heat, moisture, ill-fitting shoes, and unusual exercises all predispose to blisters. If excessive blisters are noted on the body, the physician should keep in mind the potential diagnosis of epidermolysis bullosa. Nail deformities, thin-appearing skin, scalp blistering and alopecia, dysphagia, and dental abnormalities are all characteristics of epidermolysis bullosa.

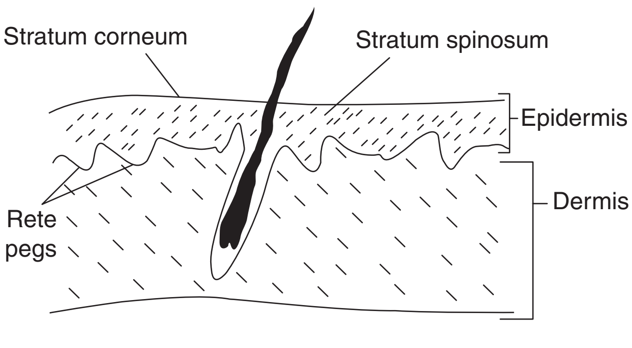

Figure 1 Diagram of the Skin

Source: Elizabeth Rothe, M.D.

Note: The epidermis, showing the top layer (stratum corneum) and the lower layer (stratum spinosum), which contains rete pegs, and the dermis layer of the skin.

Blisters may be left alone if they are not bothering the patient, but if they are causing pain, they are treated by first draining the fluid. This prevents additional intralesional pressure and pain, which might potentially worsen the original injury. This is done by lancing the blister at one of the edges with a sterile blade. The blister roof should be maintained to prevent infection, reduce pain, and provide a natural dressing for the wound. Hydrocolloid dressings may be helpful in promoting re-epithelialization and can also provide protection.

Prevention of blisters can be accomplished by taking steps to decrease the points of friction. Moisture can be decreased by using moisture-wicking socks, using drying powders such as talcum or alum, or using antiperspirants on the feet. In addition, using two pairs of socks composed of different materials, applying petroleum for lubrication, using neoprene insoles, and soaking the feet in 10% tannic acid solution to thicken the skin have been suggested as methods to prevent blisters.

Calluses result from long-term, repetitive friction. They consist of hypertrophied skin and are most often seen on the hands and feet. They are typically painless and often confer a competitive advantage to the athletes for their particular sport. They may be pared down with a surgical blade if desired. The differential diagnosis of calluses includes warts and corns. A careful clinical exam is warranted, as warts can occur within calluses and can therefore be well disguised. Calluses may be prevented by wearing synthetic socks and properly fitted athletic clothing and equipment. Petroleum jelly may also help prevent calluses.

The toenails are particularly susceptible to pressure injuries. *Jogger's toe* occurs on the longest (most often, the first) toe. It is a result of the toe hitting the end of the toebox repeatedly. Jogger's toe is exacerbated by running downhill. The toenail becomes thickened and darkens, and develops horizontal ridges. These are the result of an initial subungual hematoma and hyperkeratosis in response to the continued trauma. A related entity is *tennis toe,* which results from the quick stops and starts in racquet sports and basketball. Soccer players can also develop this in response to repetitive kicking. Jogger's toe will often resolve on its own. Evacuation of the hematoma by puncturing the nail is controversial, but if the hematoma is large, it may prevent loss of the nail. This is best accomplished with electrocautery to prevent infection. Rest and warm soaks are more helpful for chronic injuries. Some runners will paint their toenails with a dark color to hide the trauma. The differential diagnosis includes fungal infection and melanoma. A potassium hydroxide (KOH) preparation slide and culture will rule out the former diagnosis. If melanoma is suspected, as when discoloration occurs in the periungual region, a biopsy should be taken. Jogger's toe can be prevented by wearing a properly fitted shoe with a tight midfoot, to prevent too much anterior movement of the foot, and a long and tall toe box. Furthermore, nails should be cut straight across, not rounded, to distribute forces more evenly across the width of the toe.

Jogger's nipples are a chafing injury that can occur in distance runners. They typically occur in men who wear coarse shirts or women who don't wear a properly fitted bra and are more common in cold weather, when the nipples are erect. Jogger's nipples consist of painful, erythematous, crusted erosions over the nipple and areola. They can fissure and bleed, resulting in streaks of blood running down the shirt. They should be treated with petroleum jelly with or without an antibiotic ointment. Those who have had them in the past should try to prevent their occurrence by using soft-fiber bras or shirts, applying petroleum, taping the nipple or using commercially available patches prior to running, or keeping the skin dry with talcum or alum powders.

Piezogenic pedal papules are herniations of fat through the reticular dermis on the posterolateral heel. They can be painful or asymptomatic, but if they are painful, they may sideline an athlete. They are often not visible if the athlete is seated or supine, so diagnosis requires the athlete to stand and apply pressure to the heel. They are often 2 to 5 millimeters (mm) in diameter and yellow-white in color. There is no cure, but heel pads have been reported to alleviate the discomfort.

Talon noir and *mogul's palm* result from intra-epidermal bleeding from shearing forces of the epidermis sliding across the rete pegs, causing intra-epidermal hemorrhage (see Figure 1). Talon noir consists of blue or black macules, most commonly seen on the posterior, lateral, or medial heels of basketball players (see photo, this page), while mogul's palm affects the hands of skiers who repeatedly plant their poles. They can be diagnosed with removal of the hemorrhage with a surgical blade. The differential may include melanoma, and if this is suspected, a biopsy should be performed. Both entities resolve on their own in 2 to 3 weeks. Talon noir can be prevented by wearing two pairs of socks, applying lubrication, and using heel pads.

Talon noir in the heels. Observe the hyper-pigmented appearance.

Source: William W. Dexter, M.D.

Runner's rump consists of hyperpigmentation from ecchymoses at the superior gluteal cleft. It results from contact of the buttocks during each stride. It resolves at times of decreased training. It is of little clinical significance.

Elizabeth Rothe and William W. Dexter

See also Dermatology in Sports; Friction Injuries to the Skin; Skin Disorders Affecting Sports Participation

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Preventing Sports Injuries

A common pronouncement on sports injuries is that they are "part of the game" and that little can be done to prevent their incidence and severity. Studies have dispelled this myth. By addressing the risk factors associated with sports injuries, especially those seen in young athletes, reductions in both *acute* and *overuse* injury rates of between 15% and 50% have been demonstrated.

Preventing Acute Sports Injuries

Preseason Fitness Preparation

Athletes should participate in a directed preseason physical conditioning program focusing on heart and lung endurance, strength, and flexibility. The conditioning program should also include sport-specific exercises to prevent injury: Swimmers and tennis players should focus on shoulder and arm conditioning, soccer players should emphasize strength and flexibility exercises for the groin and legs, and so on.

The team physician should use the off-season to help the athlete, where appropriate, address a previous injury with an exercise program. For example, the football player who has sustained a sprained ankle the previous season should be encouraged to work on a program to build strength and flexibility in the ankle dorsiflexors and evertors.

Wherever possible, teams should be encouraged to employ the services of athletic trainers or physical therapists, who can assist the team physician in instituting and monitoring this preparticipation fitness program.

Proper Warm-up and Cooldown

The benefits of warming up and cooling down (sometimes called "warming down") are well established: improved performance, psychological preparation, creating a comfort zone for the activity itself, and relieving the aches and pains of vigorous athletic activity.

Most important, though, the warm-ups and cooldowns prevent injuries from occurring.

Acute injuries are much more likely to occur when the muscles, tendons, and ligaments are "tight" or "cold." Tissues that have not been warmed by increased blood flow and then lengthened with gradual stretches are less pliable. Thus, they are at a greater risk of being torn during the normal twists, turns, and stretches of sports. Less pliable tissues are also more susceptible to overuse injuries.

Another important reason to properly prepare for exercise is that warm-ups improve coordination/proprioception and minimize the risk of accidents—a slip, fall, or trip.

Additionally, studies have shown that beginning vigorous exercise without a gradual warm-up—sudden strenuous exercise (SSE)—puts athletes at risk of cardiovascular difficulties. Remember too that good preparation improves performance.

The intensity and duration of the warm-up and cooldown vary with each athlete. To achieve optimal elevation in body temperature and heart rate, the well-conditioned athlete probably requires a longer, more intense warm-up than a less well-conditioned person.

Irrespective of the conditioning level of the athlete, every workout should include five stages: (1) limbering up (5 minutes), (2) stretching (5–10 minutes), (3) warm-up (5 minutes), (4) primary activity, and (5) cooling-down and cooldown stretching (10 minutes). For more on the five stages of a workout schedule, see below.

A team whose players experience a disproportionate number of acute injuries such as sprains and strains may not be doing enough pre- or post-activity preparation, and if so, the team physician should address this issue with the person responsible for this area.

The Five Stages of a Workout

Limbering Up (5 minutes)

One of the most common mistakes athletes make is not limbering up before stretching. Muscles need to be warmed before they can be safely and effectively lengthened during the stretch session.

In the limbering-up stage, athletes should raise their body temperature by 1.5° or 2° above normal before stretching. When the body temperature is raised by a couple of degrees, the athlete is making his or her muscles and tendons more lubricated and elastic. The joints increase their secretions, and so there is less friction. The transmission of nerve impulses into the muscle fibers is more efficient, and the reflexes also improve.

The limbering-up phase is complete when the athlete breaks into a sweat.

The kinds of exercise that are ideal for the limbering-up session include the following: stationary bike riding, a light jog, a brisk walk, rope skipping, using a rowing machine, or using a stair-climbing machine.

It is not necessary to become tired during the limbering-up period. The goal is simply to warm the muscles in preparation for stretching.

Stretching (5–10 minutes)

After limbering up, do between 5 and 10 minutes of stretching exercises. As the athlete gets older, flexibility decreases. The older the athlete, the more important it is that he or she take the time to stretch. Also, athletes who have specific trouble with injuries should focus on the appropriate areas, both before and after the activity.

Stretching improves flexibility. As seen in the section on flexibility conditioning, stretching should not be painful. During each exercise, stretch to the point of tension, known as the "action point," and hold it for between 30 and 60 seconds, depending on preexisting flexibility. By not overstretching, the exerciser can relax and hold each position longer.

"Ballistic" stretching, when the exerciser bounces up and down to create the stretch, is not recommended because of potential injury to muscles resulting from stretching and contracting them too quickly.

In addition to stretching all the major muscle groups before exercising, the athlete may need to pay special attention to specific stretches for different sports demands. For example, tennis players need to devote extra time to stretching out their upper backs, shoulders, and necks, as well as their calves, Achilles tendons, and ankles. Runners need to focus on their lower backs, quadriceps, hamstrings, calves, and groin muscles.

It may also be necessary to spend additional time stretching areas that are naturally tight or ones that have been previously injured.

Remember not to overstretch and to hold each stretch for between 30 and 60 seconds. Do each stretch between one and three times, depending on preexisting levels of flexibility, area-specific tightness, previous injuries, and the chosen sport or fitness activity.

Warm-Up Prior to Vigorous Activity

The warm-up session should ideally last 10 minutes.

The activity selected for the warm-up should mimic the primary workout activity. This is to maximize coordination for the sport and in so doing minimize the risk of accidental injury. For instance, joggers should perform a walk-jog, then slowly increase to a run. Swimmers should start with a few slow laps. Players of racquet sports should rally with their partners or by themselves (including service), and golfers should take practice strokes.

When warming up for an endurance health fitness activity such as running, swimming, aerobics, or biking, the heart rate during the warm-up should be 50% of the maximum heart rate.

Primary Activity of Workout

Cooling Down (5 minutes) and Cooldown Stretches (5 minutes)

Never end any vigorous physical activity suddenly. A 5-minute cooling down period helps prevent sudden changes in the cardiovascular system that can cause light-headedness or even fainting.

Gradually slowing down is as important as gradually warming up. Cooldown should be done in the same way as the warm-up—with gentle, easy movements that return the heart rate to normal. Joggers should gradually slow down to where they are walking. Swimmers should take their last few laps slowly. Even racquet sports players need a period during which their heart rate slows gradually; squash and racquetball players who work out in fitness facilities may have the opportunity to jog, then walk on a treadmill, cycle slowly on a stationary bike, or gently use a rowing machine.

Stretching for 5 minutes after exercise prevents the muscles from tightening too quickly. It may minimize muscle discomfort and may also be helpful in maintaining flexibility. Perform an abbreviated version of the exercises in the prestretch portion of the workout. Again, pay special attention to those specific areas that the sport has stressed.

Safe Playing Conditions

Sports injuries are less likely to occur if the athlete is using proper facilities. Examples include the following:

- Playing fields free of potholes, glass, or other debris and with padded posts
- Basketball/volleyball courts free of any debris or potentially dangerous objects (discarded sweatpants, water bottles, etc.) and without any wet spots from sweat, spillage, or roof leaks (If any occur during games or practice, they should be immediately wiped up.)

Coaches and team physicians should involve themselves in inspecting the playing conditions before the sports event.

Addressing Extreme Temperatures

The safety of sports participation can be directly affected by the ambient climate at the time of participation. A dramatic example of this is the Massachusetts Commonwealth Games of 1999, when a number of athletes were inadequately prepared for the extreme heat and humidity during the competition. Heat and cold acclimatization as well as altitude acclimatization are known physiological processes that can be facilitated by a proper progression in training in these environments. Both the International Federation of Sports Medicine and the American College of Sports Medicine have published position stands and recommendations on athletic participation in extreme heat.

Athletes who exercise outside in hot and humid or cold and wet conditions can suffer from a variety of ailments. Injuries due to overheating and overcooling are especially prevalent among runners. In fun runs, for instance, the most serious injuries are related to the inability to keep the body temperature from rising too high. This increase in temperature occurs when the body produces heat at a faster rate than it can disperse heat. In short races of 10 kilometers (km; 6.2 miles) or less, increased body temperature (*hyperthermia*) occurs in conjunction with the tiredness caused by the heat; fainting and dizziness can occur, even on relatively cool days. In longer races on warm days, these heat problems are common. On cool or cold days, especially when it is wet and windy, the risk to participants in running races is related to low body temperature (*hypothermia*).

Athletes may become too hot or too cold, depending on the prevailing temperature, humidity, wind conditions, and clothing.

Overheating: Hyperthermia

During vigorous exercise, the amount of heat produced by the working muscles is 15 to 20 times what they produce at rest. This elevated rate of heat production can raise the body temperature rapidly. As body temperature rises, the brain senses this and increases the amount of blood sent to the skin and stimulates sweating. The skin is then cooled by sweat evaporation. If the cooling effect is inadequate, the body will overheat. Injury will occur when the person becomes too hot, that is, when body temperature goes higher than 104 °F (40 °C).

During long training sessions or athletic events, the amount of body fluid lost through sweat can cause runners to lose a lot of weight. The loss of weight is directly related to how much fluid the athlete has lost and can be equal to 6% to 10% of total body weight. This water loss is medically known as dehydration. Severe dehydration will cause a reduction in the athlete's capacity to sweat and, therefore, increases the risk of getting too hot, which may lead to heat stroke, heat exhaustion, and muscle cramps. Children are much more likely to get overheated and overcooled than adults and should be watched carefully during training sessions and games in hot conditions.

The risk of heat injuries can be reduced by dressing appropriately for the weather. It is also possible to reduce dehydration during long training sessions by drinking plenty of fluids, mainly cool water. Sometimes during shorter exercise sessions, the participant's body may heat up without the person seeming to lose weight; therefore, athletes should always be alert to the problems of heat stress. Athletes should always avoid drinking liquids containing high amounts of sugar (e.g., soft drinks) immediately before or during runs. Many sports drinks contain high concentrations of glucose, which delay the water's absorption into the system. Also, sports drinks' much-touted extra electrolytes are not necessary because electrolyte loss from sweating is minimal in the trained athlete who performs relatively short-term exercise. Most of the sugar and electrolytes can be replaced through a balanced meal after the exercise. Athletes who prefer the flavor of sports drinks should dilute them with water by half.

Athletes who do vigorous exercise frequently—especially during extremely hot temperatures—should make sure that their diets contain plenty of salt, potassium, and calcium. These are the essential minerals lost through sweat. Salt tablets are not a good idea. They are difficult to digest, and consequently, the salt doesn't get into the system where it can provide any benefit. Salt tablets may also upset the chemical and electrolyte balance of the body.

Alcohol should never be used to replace lost fluids.

In hot climates, athletes should avoid exercising outside at midday, when the temperature is at its peak. It is best to exercise in the early morning or late evening. Avoid strenuous workouts when the humidity is high.

Overcooling: Hypothermia

The body can lose too much heat when the rate at which a person loses heat is greater than the rate at which he or she produces heat. Even on moderately cool days, if a runner's pace becomes too slow and/or if the weather conditions become cooler during the run, the runner can become too cold. Several deaths have been reported due to cold conditions during fun runs, especially in the mountains. Being too cold is common for inexperienced marathon runners, who frequently run more slowly in the second half of the race, but as they slow down during the race, especially on cool, wet, or windy days, they can suddenly become too cold. Early signs and symptoms of being too cold are shivering, a false sense of well-being, and an appearance of intoxication. As the body temperature drops further, the shivering may stop, and excessive drowsiness and muscle weakness may occur, with disorientation, hallucinations, often a belligerent attitude, and finally unconsciousness or death.

Injuries caused by cold temperatures are preventable largely through appropriate use of protective clothing. The appropriately clothed athlete can withstand a wide range of temperatures. Obviously, wearing the appropriate clothes to help keep the body cool will be very helpful in hot temperatures. For example, light-colored clothing made of cotton is much better than dark-colored clothing made of synthetic fibers such as nylon. In cold weather, insufficient clothing will not provide the protection necessary for a runner to keep warm, especially near the end of the race, when he or she slows down and the heat production of the body is less than that necessary to keep warm. On a cool day, the clothing worn should consist of multiple thin layers of cotton fibers. A polypropylene fabric may be worn near the skin. This clothing should be covered with an easily removed Windbreaker (preferably human-made nylon). As the athlete gets warm, clothing can be removed to allow sweat to evaporate or dry. However, when the pace gets too slow for the runner to keep warm, the clothes can be put back on. In addition to being more effective at retaining body heat, *multilayering* allows athletes to remove layers when they get warm. When the clothing is nonconstricting, multilayering helps prevent sweat freezing on the body. Appropriate headgear should not be neglected during cold weather, as the body loses most of its heat through the head. In very cold weather, the face, nose, and ears should also be covered, as these areas are the ones most likely to become frostbitten. During wet weather, waterproof clothing is essential.

It is also advisable to wear sweatsuits while warming up during cool or cold weather. The insulation provided helps muscles, ligaments, and tendons get warmer and more flexible, which contributes to preventing both acute and overuse injuries.

Appropriate Safety Equipment

Protective safety equipment has been developed and recommended for many different sports. The purpose of such equipment is to help prevent and reduce the severity of injuries. The use of safety equipment is usually an outcome of research by health professionals who have identified a high risk of injury in a particular sport or recreational activity. The use of safety equipment may be advocated by the government, national medical organizations, public health professionals, safety groups, national governing bodies of sports, or sports associations to prevent many different types of injuries, especially catastrophic injuries. It is the job of the coach and the team physician to oversee the equipment personnel in making sure that athletes wear safety equipment appropriate for their sport and that the safety equipment worn be sized correctly for the athlete.

Preventing Overuse Sports Injuries

After studying millions of overuse injuries, sports medicine physicians have identified risk factors that are either *intrinsic* or *extrinsic.*

Intrinsic Risk Factors

- Previous injury
- Poor conditioning/muscle imbalances
- Anatomical abnormalities
- Nutritional factors
- Growth (in children)

Extrinsic Risk Factors

- Training errors, including abrupt increases in the intensity, duration, or frequency of training
- Inappropriate workout structure, including improper footwear

Risk factors are the key not only to preventing sports injuries but also for diagnosis, treatment, and rehabilitation. They often explain why some athletes sustain overuse injuries while others do not. Of the risk factors associated with overuse sports injuries, the ones most to blame are *previous injury, poor conditioning/muscle imbalances, anatomical abnormalities,* and *training errors.*

Often, two or more risk factors can cause an overuse injury to occur. For example, an athlete may have dramatically increased the amount of training over a relatively short period of time while training in worn-out footwear and on training surfaces that have become harder because of climatic changes such as lack of rain.

An understanding of all the risk factors associated with overuse injuries is a crucial first step toward taking a comprehensive approach to injury management.

Intrinsic Risk Factors

Previous Injury

The most reliable predictor of injury is previous injury. Most athletes who get injured are destined to reinjure themselves. This underlines the inadequacy of injury management, especially rehabilitation. Unless rehabilitation is done, tissues weakened by injury do not fully regain their strength, which puts them at risk of getting damaged again.

Proper rehabilitation may break the injury-reinjury cycle, but only when the program emphasizes return to *full function,* not just symptom relief.

Poor Conditioning

Unfit athletes are much more likely to get injured than those who are in shape. Studies have shown that injuries tend to occur early on in the sports season, when athletes are generally less conditioned than later in the season. This applies to overuse injuries, too, because an unfit athlete's body is less able to cope with the repetitive stresses of his or her chosen activity. It is extremely important that athletes do not go from being relatively inactive for an extended period straight into rigorous training, such as going directly into the football season after a summer "off." Athletes should be given off-season strength and flexibility programs by their coaches. These programs should address "weak" areas that have been the site of previous injury.

It is also important to keep in mind that being fit for one sport does not mean that an athlete is necessarily fit for another. For example, long-distance runners may not be immediately fit for intensive swimming training—and vice versa—so it is important if they switch over that they do exercises to condition their bodies and work themselves slowly into the training.

Muscle Imbalances

Imbalances between muscle groups near one another are common in athletes, and the team physician should be aware of their significance. Muscle imbalances may be due to asymmetry of muscle use reflecting the special demands of the sport itself. For example, ballet dancers often have excessive strength and tightness in the abductors of the hip and relative weakness of the adductors of the hip. Additionally, adolescent athletes may have muscle imbalances induced by the growth process. About the anterior thigh, there is a tendency for the lateral muscles to become stronger and tighter and the medial muscles to be relatively weaker. Usually, these muscle imbalances are seen in the lower back and legs.

The consequence of these imbalances is threefold. First, they can cause stresses to the underlying tissues; second, they can pull certain parts of the anatomy out of alignment; and third, they may interfere with proper running form. All three can lead to overuse injuries.

Stresses Caused by Muscle Imbalances. Tight muscles can cause any number of overuse injuries, especially in running sports. Excessive tightness in the muscles that run along the outside of the thigh, the iliotibial band, can create pressure on the outer side of the hip (*trochanteric bursitis*) and the outside of the knee (*iliotibial band friction syndrome*). Tight muscles and tendons in the back of the lower leg (gastroc-soleus/Achilles tendon unit) can cause Achilles tendinitis, an inflammation of the thick cord of tissue that connects the calf muscles to the back of the heel, and *plantar fasciitis,* an inflammation of the connective tissue underneath the foot that connects the toes to the heel (*plantar fascia*).

Alignment Problems Caused by Muscle Imbalances. The most frequent sites of alignment problems caused by muscle imbalances are the back and the knee.

Low back pain is common in athletes. Often, it is caused by tightness in the muscles in the front of the hip (*psoas*) and behind the thigh (hamstrings) relative to tightness in the stomach muscles (abdominals) and the muscles in the front of the thigh (quadriceps). The spinal postural stabilizing muscles may also be relatively weak. Such an imbalance can cause a posture problem called "swayback" (*lordosis*), in which there is excessive front-to-back curve in the lower spine. This in turn predisposes the athlete to serious overuse injuries of the lower back, such as a herniated disk and spondylolysis.

Patellofemoral pain is another frequent problem in athletes, especially those who have to do a lot of running during training or competition. The most common patellofemoral problem is the patellofemoral pain syndrome, which is usually caused by maltracking of the patella in the *trochlea,* the anterior groove of the femur. A number of factors may contribute to the imbalance of forces at the patella that result in pain, including anatomic factors and muscle imbalances. The patellofemoral pain is caused by an imbalance between the muscles on the inner and outer sides of the quadriceps, the *vastus medialis* and *vastus lateralis,* respectively. The end result of this imbalance is a tendency toward lateral tracking and posturing of the patella in its trochlear groove. With early institution of appropriate exercises to strengthen the vastus medialis and stretch the vastus lateralis, this imbalance can often be corrected and the pain relieved.

Foot Strike Problems Caused by Muscle Imbalances. The third problem associated with muscle imbalances is their effect on the biomechanics of running. This generally affects athletes engaged in sports that involve a lot of running.

Running causes tightness in certain areas, most often the psoas muscles in front of the hip, the hamstring muscles in the back of the thigh, and the gastroc-soleus/Achilles tendon unit in the back of the lower leg.

Athletes with this pattern of tightness tend to have a much briefer than normal foot strike when running, because their muscles are so tight that they cannot perform the optimal relaxed heel-to-toe foot strike. With each step, the time taken for each foot to touch the ground is less, and thus the feet absorb more stress every time they hit the ground. Although the time differential may seem relatively minor, when one considers that a runner may take 10,000 steps every hour, the consequences may be dramatic.

Anatomical Abnormalities

One of the most common reasons some athletes sustain overuse injuries while others do not is that they have anatomical abnormalities that place additional stress on the surrounding structures. In daily activities, these anatomical abnormalities do not cause problems, but when they are subjected to the repetitive stresses of running, overuse injuries may occur. The most common anatomical abnormalities of the lower extremities are flat feet, feet that excessively *pronate* (roll inward when the athlete runs), high arches, knock-knees, bowlegs, and turned-in thighbones (*femoral anteversion*).

Flat Feet/Excessive Pronation (Pes Planus). Some people have naturally flat feet that excessively turn inward ("pronate") when they run (Figure 1). A certain amount of natural pronation occurs during the "running cycle" with each step any athlete takes. Excessive pronation, however, can be harmful. It causes increased stress throughout the lower extremities. In such cases, overuse injuries may occur. In the foot itself, the most common overuse injuries associated with flat feet and feet that excessively pronate are stress fractures and posterior tibial tendinitis.

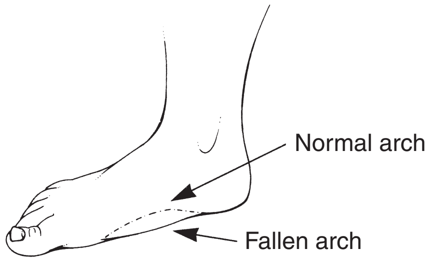

Figure 1 Flat Feet (Pes Planus)

Flat feet and feet that excessively pronate not only cause problems in the foot but may also affect the entire lower extremities, including the knee and hip, because both these conditions cause inward rotation of the legs.

Other lower extremity problems thought to be caused in part by flat feet or feet that excessively pronate are compartment syndrome in the lower leg, patellofemoral pain in the knee, and trochanteric bursitis in the hip.

High Arches (Pes Cavus). High arches, or "claw foot" as this condition is sometimes known, make the feet inflexible (Figure 2). The rigidity of this kind of foot makes it susceptible to overuse injuries.

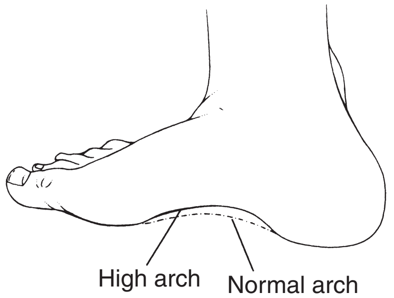

Figure 2 High Arches (Pes Cavus)

It also results in overuse injuries in the lower leg because its inflexibility causes the force to be transmitted to the structures above.

Athletes with high arches are susceptible to stress fractures in the foot, lower leg, upper thigh, and pelvis; plantar fasciitis (heel spurs); and Achilles tendinitis.

A person with high arches may also develop a *hammer toe,* in which the second toe becomes buckled and cannot be straightened. A high arch causes the big toe to slide under the second toe when the athlete runs, causing the hammer toe condition to develop.

Knock-Knees (Genu Valgum). Knock-knees create serious problems for the knee joint. Excessive inward angling at the point where the thigh and lower leg meet (*Q angle*) causes the athlete's weight to be borne on the inside of the knee (Figures 3 and 4). A Q angle greater than 10° in men and 15° in women is said to predispose that person to knee problems if he or she participates in a sports program that involves extensive running. Knock-knees are a common cause of patellofemoral pain syndrome, the most common diagnosis seen in the sports clinic.

Bowlegs (Genu Varum). Bowlegs are the opposite of knock-knees—they bend outward instead of angling inward. Athletes with bowlegs are at greater risk for sustaining problems on the outer side of the knee, especially iliotibial band friction syndrome. Having bowlegs creates a longer distance over which the iliotibial band must stretch, making it tighter over the outer side of the knee joint, where the symptoms develop. However, it should be noted that many athletes with bowlegs participate in distance running without any problems (Figure 5).

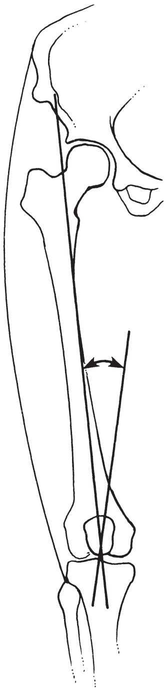

Figure 4 Q Angle

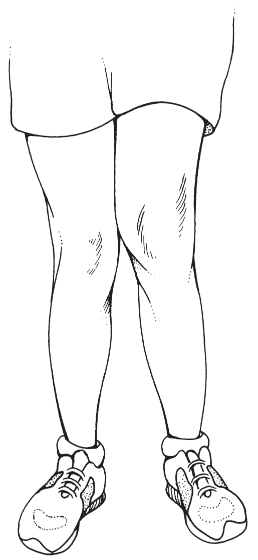

Figure 3 Knock-Knees (Genu Valgum)

Turned-In Thighbones (Femoral Anteversion). At birth, almost all infants have anterior rotation of the femoral neck with respect to the distal femur (anteversion). There is a progressive tendency with growth and maturation for the degree of femoral anteversion to decrease. However, in certain cases, anteversion does not decrease or was initially so excessive that the end result is an inward facing of the entire femur when the athlete stands with feet together. Often, femoral anteversion, when combined with a compensatory external tibial torsion, can increase the lateral torque at the patellofemoral groove and contribute to the onset of patellofemoral pain. Because it so often results in overuse sports injuries, the combination of femoral anteversion, genu valgum, external tibial

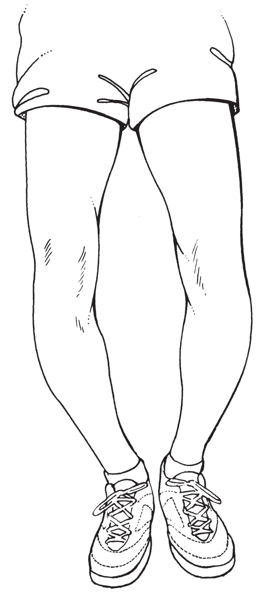

Figure 5 Bowlegs (Genu Varum)

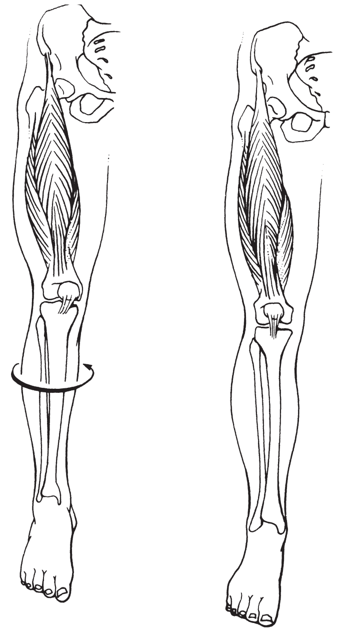

Figure 6 Femoral Anteversion

torsion, and pes planus has been dubbed *miserable malalignment syndrome* (Figure 6).

Unequal Leg Length. It is not uncommon for people to have one leg longer than the other. This can create problems, especially in the longer leg. For instance, in the longer leg, the iliotibial band (the thick swathe of tissue that runs down the side of the leg from the hip to just below the knee) must stretch over a longer distance, which may cause inflammation of this tissue where it passes over the side of the knee joint. Also, a person with one leg longer than the other tends to run with his or her spine curved slightly sideways. As a result, wear and tear can occur on the concave side of the spine.

Nutritional Factors

The relationship between three distinct but interrelated conditions—eating disorders, menstrual irregularities, and stress fractures—is known as the *female athlete triad.* Those responsible for the health of female athletes should familiarize themselves with this phenomenon.

Female athletes have more eating disorders than sedentary women. The combination of poor eating habits and high activity level can cause a woman's fat level to drop below the level necessary for normal menstrual function. When women of reproductive age stop having their periods (amenorrhea) or have periods irregularly (oligomenorrhea), they lose much of the estrogen necessary for the bone rebuilding that normal bodies perform on a continuous basis. This causes premature osteoporosis, a disease that causes the bones to become thinner and more brittle, which in turn predisposes the athlete to stress fractures. Among female athletes with menstrual irregularities, there is an almost tripled incidence of stress fractures. The most common sites of stress fractures in female athletes are the back, hip, pelvis, lower leg, and foot.

The Growth Factor

Until quite recently, overuse injuries were seen only in adults, most often highly trained elite athletes and "weekend warriors"—sedentary adults who do no athletic activity during the week and then play three sets of tennis on Sunday. Because of this pattern, physicians thought that overuse injuries such as tennis elbow resulted from too much stress on aging bones, muscles, tendons, and ligaments in a short period of time. However, with the rise of rigorous, repetitive sports training regimens for children, it has been discovered that children are even more likely than adults to sustain these overuse syndromes.

Children are more susceptible than adults to overuse injury because growth is the fundamental feature of childhood. Growth makes children vulnerable to overuse injuries for two reasons: (1) the presence of growth cartilage and (2) the growth process itself.

The team physician who is responsible for the sports health of young athletes must be aware of the significance of these two components of the growth factor.

Growth Cartilage. Growth cartilage is found at three main sites in the growing child's body: (1) the growth plates near the ends of the long bones, (2) the cartilage lining the joint surfaces (articular cartilage), and (3) the points at which the major tendons attach to the bones. Until a child stops growing, growth cartilage is present, and it is more easily damaged by repetitive microtrauma than thin, hard, fully formed adult bone cartilage. This is of particular concern at the joint surface. And because this cartilage is "prebone," injuring it may have serious consequences in later life.

The Growth Process. The major role of growth cartilage in predisposing children to overuse injury is now well-known in the medical community. What is not as well recognized is that overuse injuries are exacerbated by the growth process itself. In the past decade, pediatric sports medicine experts have devoted an enormous amount of research time to unraveling the mysteries of growth and to discovering how and why it increases the risk of overuse injuries in children.

Research has identified the chief culprit: the tightness in growing muscles and tendons. The muscles and tendons do not grow at the same rate as the bones but instead must stretch to keep pace with the growth of bone. During the adolescent growth spurt, the bones in children's legs grow so quickly that a height increase of 2 centimeters in a month is not uncommon. But because the muscles and tendons spanning these rapidly growing bones do not elongate as quickly, they get much tighter. This tightness is particularly noticeable in muscles that cross two joints. The loss of flexibility, although temporary, increases the likelihood of overuse injuries, particularly in the knee and back.

Extrinsic Risk Factors

Errors in Training

Training error—usually "too much too soon"—is the primary cause of injury, especially overuse injury. Injuries can develop when athletes suddenly increase the *frequency, duration,* or *intensity* of their workouts.

Frequency refers to *how often* the athlete trains.

Duration refers to *how long* the athlete trains.

Intensity refers to *how hard* the athlete trains. Not only does intensity encompass factors such as how far or how fast a person jogs or how heavy a weight he or she lifts; it also refers to less obvious aspects of the exercise regimen, such as the hardness of the training surface on which the athlete is exercising. Track athletes can consider that they have significantly increased the intensity of their workout if they switch from running on grass or clay to road running or from running primarily on flat surfaces to running on hills. The same applies to football players who switch from natural to artificial surfaces. Playing on a softer surface is not always less stressful; for instance, running on sand stresses the Achilles tendons and predisposes the athlete to tendinitis in that area. Sometimes "intensity" is subtle: A more tightly strung tennis racquet provides a more intense workout for the player's arm. In general, it is recommended that careful medical monitoring should be done for any athlete training more than 18 hours/week. Furthermore, it is recommended that increases in training volume should not exceed 10% per week.

Inappropriate Footwear

In sports that involve a lot of running and jumping activity, athletes exert forces of 3 to 10 times their body weight with each step. That force is absorbed by the running surface, the shoe, and the foot and leg. The less force the limb absorbs, the less risk there is of overuse injury. That explains why it is better to train on slightly softer surfaces such as clay or grass than on cement or asphalt, which have less "give." It also explains why shoes are the most important item in most athletes' wardrobes.

Shoes are especially important for track athletes. The right footwear makes for an enjoyable, injury-free running experience, while the wrong footwear can cause discomfort and ailments ranging from ankle sprains to heel spurs to knee cartilage tears.

Basketball players also need to wear shoes with adequate, appropriate shock absorption properties.

Technological improvements in footwear in the past decade have contributed to a decline in many footwear-related overuse injuries.

Improper Workout Structure

One of the most common reasons why athletes get injured is because they do not prepare their bodies for the immediate demands of exercise with a structured workout that includes warm-up and cooldown periods.

Less pliable tissues are also more susceptible to overuse injuries: Tiny tears may occur due to repetitive, low-intensity stretching of inflexible tissues. Overuse injuries of a joint can develop because the surrounding tissues are not warmed up and stretched, which restricts the joint's range of motion and may cause grinding of the cartilage against bone or cartilage against other cartilage.

The intensity and duration of the warm-up and cooldown vary with each athlete. A well-conditioned athlete probably requires a longer, more intense warm-up—compared with a less well-conditioned person—to achieve optimal elevation in body temperature and heart rate.

Irrespective of the conditioning level of the athlete, every workout should include five stages: limbering up (5 minutes), stretching (5–10 minutes), warm-up (5 minutes), primary activity, and cooling-down and cooldown stretching (10 minutes). Refer to the box on pages 113 through 115 for more details on the five stages of a workout schedule.

Conclusion

A major obstacle to developing injury prevention strategies is the lack of epidemiological data on injury rates in most sports. Without sound baseline data, the effect of measures to enhance sports safety cannot be gauged.

In 1998, the International Federation of Sports Medicine (FIMS) and the World Health Organization (WHO) released a joint consensus statement on children and sports. One of the central themes of the document was injury prevention. This consensus statement called for a number of initiatives to be adopted by sports governing bodies, including the collection of statistics on sports injuries.

This statement also called on health professionals to take steps to improve their knowledge and understanding of the organized sports environment as well as the risk factors associated with organized sports participation.

Lyle J. Micheli

See also Femoral Anteversion (Turned-In Hips); Flat Feet (Pes Planus); Knock-Knees (Genu Valgum); Miserable Malalignment Syndrome; Protective Equipment in Sports; Q Angle; Risk Factors for Sports Injuries; Static Stretching; Strength Training for the Young Athlete; Stretching and Warming Up

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PRICE/MICE

PRICE/MICE is a therapeutic modality that uses *p*rotection, *r*est/*m*odified activity, *i*ce, *c*ompression, and *e*levation to improve healing after an acute injury. The physical therapist traditionally applies this modality to improve the impairments and functional limitations that can be caused by an injury. A successful outcome in the management of any acute injury depends on immediate intervention. PRICE/MICE is one example of immediate injury care.

PRICE/MICE is used in the treatment of acute injuries such as fractures, sprained joints, and/or strained muscles. PRICE/MICE can decrease pain, reduce swelling, protect the injured area, and promote healing. When an injury occurs, there is swelling and pain, with difficulty moving the affected area. Immediate application of PRICE/MICE within 15 to 20 minutes after an injury can reduce the duration of healing by several days or weeks, depending on the injury.

Protect/Rest/Modified Activity

Protect, rest, or modified activity is recommended for the first 24 to 72 hours after an injury. This will allow time for the injury to heal. As soon as possible, the athlete should be evaluated by a physician, who will determine the appropriate level of activity depending on the severity of the injury. Protect/rest may include stopping the activity or modifying the activity. For example, a splint, orthotic, and/or crutches may be prescribed to protect and rest a severely sprained ankle. An athlete who sustains a mild injury may be allowed to participate in sports provided the injured area is supported and/or the activity is modified.

Ice

Ice should be applied as soon as possible after the injury to decrease pain, swelling, and bleeding. Ice will effect a decrease in tissue temperature, therefore slowing down the inflammatory process. Ice should never be applied directly to the skin but should have a thin protective layer, such as a moist towel. Ice could be applied in the form of a cold pack, or it could be as simple as a package of frozen vegetables. In the acute management of soft tissue injuries, applying ice immediately after an injury can reduce tissue temperature by 10 to 15 °C. Intermittent application of ice at 10-minute intervals has been shown to be more effective in cooling human tissues. Ice application may be most effective when combined with exercises. The cooling effect reduces pain, spasm, and neural inhibition, which makes it possible to begin exercises earlier.

Compression

Compression is a gentle pressure or force that will reduce swelling and pain. Compression can be achieved by applying a bandage with gentle pressure to reduce swelling. The bandage should not be applied too tightly or in a circular fashion around the extremity, to avoid circulatory impairment.

Elevation

Elevation of the injured part is necessary to prevent pooling of blood. The rationale of raising the injured extremity above the heart is to decrease the hydrostatic pressure and reduce the accumulation of interstitial fluid.

Michelina Cassella and Kathleen Richards

See also Fieldside Assessment and Triage; Principles of Rehabilitation and Physical Therapy; Team Physician

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Prickly Heat

Athletes are particularly susceptible to prickly heat, otherwise known as heat rash, or milaria rubra. Prickly heat is a superficial skin irritation characterized by red skin, small bumps, and a feeling of itchiness or discomfort. Prickly heat occurs when heat and sweating are excessive. It is most often found on the body in areas where the clothing is tight or occlusive. Because most athletes are predisposed to heavy sweating and often need to wear tight clothing for uniforms or to reduce air friction, they are afflicted by prickly heat quite frequently.

Prickly heat is named for the "prickly" sensation present on appearance of the rash. The rash appears as a pink or red discoloration to the skin, often with bumps or small blisters. It may itch or feel prickly and is mildly to moderately irritating to the athlete. The rash is associated with exposure to heat or heavy sweating. It occurs when the sweat glands become blocked. The glands rupture, and the sweat they contain irritates the surrounding skin, causing a red, inflammatory reaction. It can also occur with overdressing or if ointments are applied to the skin, as these may block the sweat glands in a similar manner.

There are a few techniques to treat prickly heat that focus on cooling the skin. Using cool baths without soap, applying a cool and wet washcloth to a local rash, dressing in fewer layers, and lowering the temperature of the skin by moving into an air-conditioned location may be helpful. Wearing clothing that is not occlusive or has the ability to wick away the sweat ("allowing the skin to breathe") will be less likely to produce a prickly heat reaction. In more extensive or uncomfortable cases, using an anti-inflammatory cream, such as over-the-counter hydrocortisone 1%, may be helpful to reduce the nuisance. It is recommended to avoid ointments because they are thicker than creams and may occlude the sweat glands.

Allyson S. Howe

See also Dermatology in Sports; Friction Injuries to the Skin; Fungal Skin Infections and Parasitic Infestations; Skin Conditions in Wrestlers; Skin Disorders Affecting Sports Participation; Skin Infections, Bacterial

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Principles of Rehabilitation and Physical Therapy

Rehabilitation is the process of restoring function after sustaining an injury and/or illness. The major goal of a rehabilitation program is to attain maximal independence in all activities of daily living (ADL), including independence in recreation and sports activity. In some cases, if this is not possible, the secondary goal is to achieve functional independence within the limits of the disability.

Principles of Rehabilitation

The major principle of rehabilitation is to safely enhance the athlete's abilities despite an existing or a developing impairment. The goals of rehabilitation include the following: to control inflammation, decrease pain, promote healing, restore function, gain independence in ADL, facilitate safe return to recreational and/or sports activities, and prevent future injury.

Definition of Physical Therapy

Physical therapy provides treatment to athletes who have sustained impairments, functional limitations, and/or disabilities resulting from an illness or injury. According to the *Guide to Physical Therapist Practice,* second edition (2001), by the American Physical Therapy Association, *impairment* is defined as a loss or abnormality of anatomical, physiological, mental, or psychological structure or function. *Functional limitation* is defined as restriction of the ability to perform, at the level of the whole person, physical actions, tasks, or activities in an efficient, typically expected, or competent manner. Disability is defined as the inability to perform the actions, tasks, and activities usually expected in specific social roles.

The Physical Therapist

Physical therapists are educated at a collegiate level and are required to be licensed in the state or states in which they practice. To obtain a valid license, the physical therapist must pass a written examination; the license to practice is issued through the Board of Registration and Medicine in that particular state.

The physical therapist performs a comprehensive examination of the athlete and designs and implements a plan of care based on the results of the examination. It is essential for patients receiving physical therapy to have a clear understanding of the role of physical therapy in their rehabilitation program. The plan of care is modified or changed as indicated by the athlete's responses to treatment.

Physical Therapy Management

Physical therapy management in the rehabilitation program includes, but is not limited to, athlete history, review of systems, comprehensive assessments of posture, muscle performance, joint integrity and mobility, pain, function, and communication. The goal of a successful rehabilitation program is not only to restore optimal functional outcomes but also to educate the athlete in health and wellness in order to prevent future injuries. The following elements are essential in the development of a comprehensive rehabilitation program.

History

A detailed history must be obtained prior to establishing a rehabilitation program. Information should be gathered from the athlete, the physician, diagnostic tests, and hospital records if indicated. The following elements should be included in the history: demographics, current medical diagnoses as well as any previous diagnoses and/or injuries, surgical intervention(s), and date(s), including outcomes, complications, and treatments. Family history, if pertinent, pain level, and current concerns, especially as they relate to activity and function, are also reviewed. The athlete's desired outcomes and goals should also be included in the assessment.

Review of Systems

Collecting baseline information prior to treatment intervention is necessary to establish goals, to monitor the effects of both therapeutic and conditioning exercises, and to identify risks for future injury. The following systems are reviewed. Cardiovascular/pulmonary review measures respiratory and heart rates and blood pressure. Integumentary (skin) review inspects skin integrity, skin color, and scar formation. Blistering, skin temperature, scar tissue pliability, texture, and sensation are also documented. If the athlete has had surgery, assessment of activities or movements that aggravate the incision sight should be noted. Musculoskeletal review evaluates gross symmetry, muscle performance, joint integrity and mobility, height, and weight. Neuromuscular review assesses balance, locomotion, transfers, and transitions. Communication review evaluates language, learning style, and cognition.

Physical Therapy Examination

Posture

According to the *Guide to Physical Therapist Practice,* posture is the alignment and the positioning of the body in relation to gravity, center of mass, or base of support. The physical therapist uses various tests and measurements to examine structural alignment. Good posture is a state of musculoskeletal balance that protects the supporting structures of the body against injury or progressive deformity. Postural deviations and/or malalignment can have a serious, negative impact on body mechanics, function, ADL, and sport-specific techniques. Identifying postural deviations leads the physical therapist to further investigate joint and muscle impairments.

Muscle Performance

The *Guide* defines *muscle performance* as the capacity of a muscle or a group of muscles to generate forces. *Strength* is the muscle force exerted by a muscle or a group of muscles to overcome a resistance under a specific set of circumstances. *Power* is the work produced per unit of time or the product of strength and speed. *Endurance* is the ability of muscles to sustain forces repeatedly or to generate forces over a period of time. The physical therapist uses standardized testing procedures to assess strength, power, and endurance in order to establish a baseline for the plan of care. Deficits in muscle performance can lead to weakness, fatigue, and functional impairment. Furthermore, athletic performance is dramatically affected if there are any deficits in muscle strength, power, or endurance.

Joint Integrity and Mobility

The *Guide* defines *joint integrity* as the intactness of the structure and shape of the joint, whereas joint mobility is the capacity of the joint to be moved passively taking into account the structure and shape of the joint surface in addition to the characteristics of the tissues surrounding the joint. The physical therapist administers standardized tests and measurements to assess both joint integrity and mobility. Abnormal integrity and mobility can place undue stress not only to the joint but also on the surrounding structures. Biomechanical limitations often cause an increase in pain and may also lead to loss of function, which can affect athletic performance.

Pain

The *Guide* defines *pain* as a disturbed sensation that causes suffering and distress. The physical therapist assesses the intensity, quality, and temporal and physical characteristics of pain that may result in impairment, functional limitations, and/or disability. Although many serious athletes perform with varying amounts of pain, prolonged chronic pain may not only inhibit the athlete's performance but also end a potential career.

Function

In physical therapy, *function* is defined as independence in all activities with maximal efficiency and effectiveness. The physical therapist assesses functional limitations with a variety of standardized tests that include balance, locomotion, transfers, transitions, and the athlete's self-report. Functional limitations in any of these areas not only lead to disability but also may lead to undue psychosocial stresses. This is especially true in the athlete.

Communication

The physical therapist is responsible for accurate communication and appropriate documentation. Clear and concise communication to the athlete, to health care providers, and to coaches and trainers with a need to know is an essential component of a successful rehabilitation program with the goal of safe return to sports.

Physical Therapy Plan of Care

The physical therapy plan of care is based on the information gathered from the examination. The rehabilitation program is based on the diagnosis, the goals of treatment, the athlete's expectations, and the anticipated course of healing. Acute injuries require early medical attention, especially if the injury affects mechanics and performance. An accurate diagnosis is necessary so that appropriate management can be planned. The goals of rehabilitation are to control inflammation, decrease pain, promote healing, and restore function. Essential components of the rehabilitation program include maintaining the athlete's physical fitness during recovery, education on preventing future injury, and specialized training to improve performance. Full recovery is independence in ADL and safe return to recreational and/or sports activities.

Treatment Intervention

Modalities

A successful treatment program depends on reducing pain, decreasing inflammation, and promoting healing. The physical therapist uses a variety of the following modalities to achieve this effect:

Superficial heat or cold is applied to increase or decrease tissue temperature, at a depth of up to 5 centimeters (cm), depending on the method of delivery. The physiological response to heat causes expansion in the blood flow, with erythema (redness), while the application of cold causes restriction in the blood flow, followed by expansion of blood flow. Both heat and cold can reduce conduction along fast and slow nerve fibers, thus decreasing pain and promoting relaxation of the tissues. In addition, applying pressure along with an ice pack reduces posttraumatic swelling. It is essential to have a proper barrier between the skin and the hot or cold pack in order to prevent skin irritation and/or damage.

Hydrotherapy is the immersion of body segments in water, for example, in a whirlpool. Water immersion promotes an increase or decrease in superficial tissue temperature in a large body part. The main goal of hydrotherapy is to decrease swelling, relieve joint pain and stiffness, and promote relaxation.

Therapeutic ultrasound is a form of deep heat that is produced by a transducer that converts electrical energy into sound energy. Ultrasound produces a thermal effect by increasing tissue temperature by 1 to 2 °C at a depth of 5 cm. The main goal is to increase tissue extensibility and to decrease inflammation, swelling, pain, and muscle spasm. In addition, ultrasound can help reduce joint contractures and scar tissue. Ultrasound should never be applied over an open growth plate.

Massage is the manipulation of soft tissues by the hands. Pressure and stretching are applied to compress soft tissue, causing an increase in circulation and, thus, promoting better muscle nutrition and relaxation. Massage prior to performing a series of exercises can enhance mobility, reduce pain, facilitate relaxation, and also reduce stress.

Transcutaneous Electrical Nerve Stimulation (TENS) is the procedure of applying controlled, low-voltage electrical impulses to the nervous system by passing electricity through the skin. TENS is often effective in the treatment of acute and chronic pain. TENS is based on the theory that the peripheral stimulation of large-diameter cutaneous afferent nerve fibers blocks pain sensation at the spinal cord through the gate control mechanism.

Neuromuscular Electrical Stimulation (NMES) is the application of electrical current to the skin to activate motor units, causing an involuntary skeletal muscle contraction. The main goal is to provide biofeedback and muscle re-education to the involved muscles. NMES has been shown to enhance muscle function postoperatively.

Iontophoresis is the transfer of topical medications in the form of applied active ions into the skin by direct current. Topical steroids are commonly administered using iontophoresis. The goals of iontophoresis are to decrease inflammation and edema, soften scar tissue, and reduce pain.

Orthotic (braces) and assistive devices are prescribed to support or immobilize a body part, to correct or prevent deformity, and/or to assist function. Devices include braces, foot orthotics, shoulder slings, splints, prosthetics, crutches, and many others. Devices such as braces restrict, control, or eliminate joint movement, while others assist movement, such as prosthetics. Some orthotic devices can help reduce pain, decrease swelling, control and enhance movement, and improve body awareness. Proper selection, evaluation, and fit of the orthoses are critical to ensure both function and safety.

Therapeutic Exercise

The *Guide* defines *therapeutic exercise* as the systematic performance or execution of planned physical movement. An exercise program enables the patient to remediate or prevent impairments and enhance function, fitness, and well-being. Therapeutic exercise may include any or all of the following: muscle strengthening and joint range of motion, aerobic and endurance conditioning, agility, balance training, body mechanics, coordination exercises, gait, and locomotion training. The selection of an appropriate therapeutic exercise program depends on the diagnosis, the surgical procedure, the stage of healing, and the degree of inflammation, pain, and patient cognition, readiness, and compliance. Teaching the patient a realistic exercise program that can be performed daily either at home or at a medical or physical fitness facility will ensure a successful functional outcome and safe return to recreational and/or sports activity. It is important to individualize the exercise program in order to meet the athlete's physical and emotional needs. Attitude, motivation, and time availability will have a significant effect on the success of the program. The overall focus of the exercise program should be to regain full, painfree, and safe independent function and return to sports.

Therapeutic exercises may be active-assistive, active, and/or resistive. The aim of resistance exercises is to regain the strength, joint stability, and neuromuscular control to perform functional and/or sports activities. Therapeutic exercise programs should be designed to apply controlled but not excessive stress to healing structures, based on the underlying pathology. The amount of resistance, repetitions, frequency, speed, and rest intervals can be varied during exercises to promote optimal loading of the muscles and joints. Simple exercises are started first, followed by more complex activities involving more than one joint. In athletes, special attention must be paid to their sport. Sport-specific exercises are introduced for safe return to sports activity.

Conclusion

An effective rehabilitation program will not only promote total functional independence with safe return to sports but also help educate the athlete on healthy lifestyle changes. Instructing the athletes in the proper care of their bodies is the responsibility of all who are involved with their care. A proper, well-designed program will not only help the athlete recover from a current injury but also help prevent future injuries.

Michelina Cassella and Kathleen Richards

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Principles of Training

Training is the method that athletes use to improve performance in their sport. Training methods have been studied extensively over the years, and some common themes can be traced through the myriad sports and events.

From a holistic point of view, athletes should be considered as living psycho-social-physiologic systems. This holistic can be expanded into five areas, which when combined, culminate in an integrated view of performance: (1) physiology, (2) biomechanics, (3) psychology, (4) tactics, and (5) health/lifestyle. All these components need to be functioning at near-optimal levels for the athlete to achieve a successful performance or a maximum training adaptation.

Stimulus

The first component of successful training is a sufficient amount of exercise to stimulate the musculoskeletal and other body systems. Only when a system is suitably stressed will it be stimulated to adapt to future recurrences of such stress. Exercise stress can be conceptualized in terms of frequency, volume, and intensity of training.

Duration

Athletes training for a marathon must incorporate "long runs" (10 miles [mi; 1 mi = 1.61 kilometers] or longer; longer than 90 minutes) into their preparation for the marathon event. By doing so, their muscles and cardiovascular system, in particular, are better prepared for the rigors of running for more than 3 hours, the time required by most of them to finish 26+ mi on the marathon course. Thus, the duration of training is a quantitative component referring to the length in time of such a long-run training session.

Frequency

Training frequency refers to the number of training sessions within a given time frame, such as a day or a week. In general, maximum aerobic adaptation is achieved from completing a long run only once a week.

Volume

Athletes and coaches often refer to combinations of these variables. Training volume refers to the product of duration and frequency of training (usually in a week).

Intensity

Intensity of effort is a qualitative component, and in endurance activities (e.g., a marathon), where distance and time are the factors to be considered, absolute intensity can be recorded as running speed. Relative intensity can be quantified as a proportion of an athlete's maximum speed or by a physiologic variable such as the percentage of maximum heart rate an athlete is training at. Intensity is generally considered the most critical factor of training. Within the training process, the correct balance of low-, medium-, and high-intensity training is critical to the adaptation process, and if too much moderate- or high-intensity training is undertaken, there is a significant risk of fatigue, which may lead to "overtraining."

Load

Training load refers to the product of all three fundamental components: (1) frequency, (2) duration, and (3) intensity. The correct sequencing of changes in volume and load throughout a training year is critical to the adaptation process.

Specificity

A second major component of training is *specificity*. Even though swimming and biking for 3 hours would provide a similar aerobic stimulus to running, the act of swimming lacks specificity; simply put, you need to practice what you wish to perform. The benefits of cross-training may be covered elsewhere; however, for maximal efficiency of training, you get the biggest benefit to eventual performance by training in the mode of exercise you will eventually compete in. Furthermore, while training in the same mode as the competition, an athlete will also attempt to mimic the speed, range of motion, and typical resistance likely to be attempted on a race day. For example, training for a mountain bike race by spending time riding easy trails will be beneficial for performance; however, if the race is over challenging terrain with obstacles, steep climbs, and fast descents, there would be greater performance gains in general if the athlete had trained at least to some extent on similar terrain. Adaptations in muscle strength, speed, and coordination are partly peripheral at the myocyte cellular level, but they are also central, with "motor memory" developed for the activities the brain, spinal cord, and neurons would otherwise be unaccustomed to.

Progressive Overload

Having chosen the appropriate mode and stimulus, the next component of successful training is that of *overload*. Systems stressed by exercise in a training schedule operate in a balance between damage and repair. For example, after a strenuous 90-minute soccer practice, players' leg muscles will show microscopic evidence of cellular damage, manifested as muscle soreness 24 to 48 hours later. This damage is limited and corrected by the immune system and local muscle factors, and if sufficient recovery time is allowed, there are microstructural improvements made such that the muscles will be better able to cope with this training stimulus. Hence, subsequent practices need to be of greater intensity or in longer sessions to achieve a sufficient stimulus to challenge those muscles. This is the principle of progressive overload: Body systems adapt when a consecutively greater stimulus is provided during the training program.

Periodization

Periodization is the organization of training into large, medium, and small training blocks, referred to as macro-, meso-, and microcycles, respectively. When the sequencing of training is correctly applied, athletes can achieve a high state of competition readiness, and during the months of hard training, they can avoid the "overtraining syndrome." A microcycle refers to a structure of separate training sessions or a small grouping of several sessions; mesocycles (3–5 weeks) are groupings of several microcycles with a predetermined training objective or performance goal, and macrocycles (12–16 weeks) reflect groupings of mesocycles within a semiannual or annual plan. Periodization provides a framework that allows a coach to formulate a specific program to achieve improvements in the physiologic, technical, or psychologic components of performance. Hence, during periods after high physiological demands have been experienced, a coach may choose to focus on technical and psychological improvements while allowing for relative physiological rest.

The researcher David Pyne (1996) listed the common features of periodized training programs as follows:

- The long-term performance goal for the season forms the basis for the training program.
- There is a progressive and cyclical increase in training loads.
- There is a logical sequence to the order of the training phases.
- There is scientific monitoring in physiology, biomechanics, psychology, and physical therapy.
- There is intensive use of recovery or regenerative techniques throughout the training program.
- Emphasis on skill development and refinement is maintained throughout the training program.
- There is an underlying improvement and maintenance of general athletic abilities.

- Each part of the training program builds on the preceding phase.

Individualization

Individualization implies that individual athletes will react and adapt differently when presented with identical training regimes. On a spectrum, there are two broad categories of athletes, with the genetically talented at one end and those with a highly developed work ethic, and perhaps a system guiding their effort, at the other. Individualized training programs with monitoring systems available to evaluate individual responses to a training load are a necessity.

Structural Tolerance

Structural tolerance implies that the body needs time to adapt to a training load. Structural tolerance is the ability to withstand weeks or months of high-volume training without the incidence of injury, illness, or fatigue, which may lead to overtraining. Through years of general and specific training, structural tolerance can be greatly improved. From a lay perspective, team sports athletes, such as soccer or football players, may be pushed beyond their individual structural tolerance during vigorous preseason training camps and may then be perceived as “injury prone” for the remainder of the season as their bodies attempt to recuperate.

Reversibility

Reversibility highlights the requirement for consistent training. As suggested by the fitness-fatigue model of Dr. Eric Bannister, fitness and fatigue are never constant, and interruptions to training caused by injury, illness, or social needs break the consistency of training that is required to achieve improvements. Loss of fitness can occur through inconsistent training, and fatigue may occur through nontraining stress factors and inadequate recovery.

All-Round Development

All-round development suggests the need for an underlying general athletic ability that is supported by a strong psychologic platform and technical ability in the various activities in which an athlete engages. Personality type plays an important role in athletic success. Unless an athlete is gifted with the personality and inherent coordination and skills fundamental to his or her sport, training may not achieve the success of others more fortunate. Within the training process, overcoming training and competition stresses promotes willpower, self-confidence, and tolerance for higher training and competition demands.

Hamish A. Kerr

See also Overtraining

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Protective Equipment in Sports

Sports injuries are common in professional sports, but the amateur is equally at risk. While many people sustain injury due to overexertion or lack of correct technique, many others sustain injuries that could have been prevented or at the very least minimized by the use of the correct protective sports equipment. Using the correct equipment can increase the career life of professional sportspersons and have a significant impact on their earning potential. For others, it may mean the chance to safely continue to enjoy their favorite sport and ensure a good quality of life.

Most sports have documented standards for protective equipment. Some athletic organizations have rules that require athletes to use protective equipment; failure to do so may result in fines or disqualification. Many organizations have established quality control standards for the manufacture of protective equipment. Compliance with these standards is voluntary, however, and cannot be enforced on the manufacturers. The onus lies on the purchaser to choose the protective equipment that will perform its function under field conditions reliably.

Protective Eyewear

The American Academy of Ophthalmology has stated that more than 90% of eye injuries can be prevented by using protective eye equipment. The most common types of eye injuries are as follows:

- *Blunt trauma:* for example, getting hit in the eye by a racquet
- *Penetrating eye injuries:* for example, from glass shards or an arrow
- *Radiation injuries:* for example, burn injuries caused by the sun's radiation to the retina of athletes who perform in the snow or on water

All these can lead to serious visual defects and possibly eye-threatening infections. Protective eyewear is thus a must for all those at risk of eye injury. However, the eyewear must follow standard specifications. The following types of eyewear do not provide adequate eye protection during sports; in fact, some of them may even be hazardous.

- Fashion sunglasses
- Regular eyeglasses
- Contact lenses
- Industrial safety glasses

The American Academy of Ophthalmology recommends that eyeglasses or goggles have lenses made of 3-millmeter (mm) polycarbonate, which is very thin, light, and impact resistant, with a 100% ultraviolet (UV) light filter to prevent radiation injuries. Neutral gray or amber lenses are good colors to filter out bright light, and polarized lenses are useful in avoiding glare on water or snow. Different sports have different requirements, as elaborated below:

- Full face protection with attached polycarbonate eyeshade: football, baseball, and the batter in softball
- *Full face protection:* field hockey goalie, ice hockey, men's and women's lacrosse, paintball
- *Goggles with polycarbonate lenses:* racquet sports, field hockey, basketball, soccer, baseball, softball, women's lacrosse, and tennis
- High-impact resistant sports goggles with polycarbonate lenses with filter for UV and excessive sunlight: skiing

Helmets

A direct hit to the skull can lead to concussion, intracranial bleeding, or skull fracture. A proper helmet can absorb blows to the skull and protect the brain. It does not, however, protect the neck.

Selecting a Helmet

- It should fit comfortably and have a firm grip. Less than 1 inch (in.; 1 in. = 2.5 centimeters) of head movement should be possible inside the helmet. Vision should not be obscured, but the forehead should be covered; however, the side and back length can vary.
- Stretching the lower jaw should be accompanied by a stretch on the chin strap, and the top of the helmet should move downward.
- There should be room for goggles or a hat under the helmet, if required. The helmet should be tried on with the additional gear.
- Helmets with vents are also available for air circulation.
- A previously damaged helmet (especially if it is cracked or if the foam lining is crushed) must not be used.

For particular sports, the following points should be kept in mind:

Bike helmets: They should be in bright colors to make the wearer easily visible.

Skiing/snowboarding helmets: They should be insulated against the cold. Head coverage should be complete, and they must have space for ski goggles.

Football and hockey helmets: They should be able to withstand multiple impacts.

Baseball helmets: The batter needs to wear a helmet to protect his or her head from a possible hit by the ball; however, the catcher must wear full-face protection.

Skateboarding/skating helmets: While bike helmets can be used, it is better to wear a helmet that can protect the back and sides of the head.

Safety Pads and Guards

There are multiple types of safety pads and guards meant for different sports. They serve to protect the skin and prevent sprains and sometimes even fractures.

Safety Pads

The shape is meant to fit the body part it is supposed to protect. It has soft padding on the inside and a harder shell on the outside. There are numerous types of pads:

Knee pads: recommended for football, hockey, inline skating, volleyball, and wrestling

Shoulder pads: recommended for football, hockey, and lacrosse

Elbow pads: recommended for football, hockey, inline skating, skateboarding, volleyball, and wrestling

Hip pads: recommended for football, hockey, inline skating, and skateboarding (they slide into the uniform easily and protect the hips)

Thigh pads: recommended for football, hockey, and cricket (they also slide into the uniform and protect the front of the thigh)

Safety Guards

A guard is a rigid structure that covers the vulnerable areas of the body, for example, the groin. Unlike safety pads, guards do not usually have padding. They are specific for different body areas:

Shin guards: They usually slide into the socks; they are recommended for football, soccer, hockey, baseball, and cricket.

Wrist guards: They are recommended for football, inline skating, skateboarding, and snowboarding.

Knee guards: They are recommended for football, soccer, hockey, inline skating, snowboarding, skateboarding, and cricket.

Elbow guards: They are recommended for football, soccer, hockey, inline skating, snowboarding, and wrestling.

Mouthguards: They fit over and are molded to the shape of the upper teeth. They are essential in some sports, such as boxing, to protect not only the teeth but also the lip, tongue, and jaw. The American Dental Association recommends mouth protection for hockey, football, basketball, volleyball, and gymnastics. Athletes who wear braces should also consider using these guards. The guard should be secure and not fall off during activity; however, it should not hinder breathing or talking.

Some Types of Mouthguards

- *Off the shelf:* ready-made, inexpensive; usually does not provide a perfect fit
- *Boil and bite:* ensures a better fit
- *Custom made:* made by the dentist and ensures the best possible fit; obviously more expensive

Care of the Mouthguard

- Brush after each use. Wash with soap once a week.
- Store in a case that allows air to flow, in a cool place. Never leave it in the sun or near a heat source.
- Replace at the first sign of any damage—for example, frayed edges, tears.

Footwear

There are different types of shoes for different sports, and these should be selected on the basis of foot type and running style.

Foot Type

The foot type can be determined by checking the footprint. Modern stores can also check the foot type using a computer, with the athlete running on the treadmill. The following foot types are usually observed (see Figure 1):

Flat feet: There is no visible arch. The footprint is visible in its entirety, and there is no inward curve between the heel and the big toe (Footprint 3).

High arches: The arch is very prominent. The footprint curve is large, and the outer edge is skinny. Sometimes there is a complete gap in the footprint between the big toe and the heel (Footprints 0 and 1).

Neutral foot type: There is a small curve inward (Footprint 2).

Running Style

One can observe the soles of current running shoes: The location that is most worn can tell you if one has a neutral strike, rolls in or out, or lands on the heels. Another method is to observe the shoes: If the wear is more on the inside of the heels, the feet are rolling inward as one runs, and vice versa. Common running styles are as follows:

- *Overpronators:* These athletes tend to roll inward with heel strike. They need more stable shoes.
- *Supinators:* They tend to roll outward during heel strike. These people need a flexible, cushioned shoe.
- *Neutral.*

Shoe Types

There are five basic shoe types that should be selected according to the foot type, running style, and game requirements.

Figure 1 Foot Type

Motion control shoes: rigid and stable shoes that control movement; recommended for pronators and also for those with flat feet

Stability shoes: for those with neutral foot types who just need support and cushioning

Cushioned shoes: for those with high arches; also for underpronators

Lightweight training shoes: fast and efficient shoes; recommended for those who don't have any feet problems

Trail shoes: offer the most traction, are hardy, and have a thick sole; for those who run on rough ground or in extreme weather

Exercising in worn-out shoes can cause problems. It makes sense to own two pairs of shoes that can be used alternately and to buy a new pair before the old ones run out. The usual recommendation is to replace running shoes between 350 and 550 miles (mi; 1 mi = 1.61 kilometers) and for heavier athletes to replace them earlier.

The following points should be kept in mind when buying a running shoe:

- Feet swell at the end of the day, so shoes should be bought in the evening.
- The shoe should be tried while standing and walking, not sitting.
- Both shoes should be tried with the socks that are commonly used.
- If the feet are unequal in size, the larger size should be bought.
- A thumbnail-width space should be left between the edge of the shoe and the big toe.
- Shoes that hurt or are not immediately comfortable should be rejected.
- Shoes should be bought according to the foot type and running style.
- The shoes should be worn around the house before starting to run in them. Even then, a short run should be done first. Any hot spot may be the forerunner of a blister.

Bracing and Taping

These can provide limited protection against injury. Bracing, however, is better as taping becomes ineffective after 20 minutes. For further information, see specific entries in this encyclopedia.

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See also Mouthguards; Taping

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Protein in the Athlete's Diet

Protein is an essential part of our daily diet; however, the dietary requirements of athletes constitute a controversial topic. There are two major schools of thought: (1) that exercise participation increases the nutritional protein requirement and (2) that protein requirements are relatively similar between sedentary persons and active athletes. Part of this controversy arises from the differences in the definition of protein requirements. Scientifically, protein needs are based on nitrogen balance. Protein metabolism is affected by the athlete's age, sex, energy intake, and carbohydrate availability, as well as the intensity, type, and duration of exercise. The functions of proteins are the building and maintenance of muscle, hair, skin, and nails, as well as nutrient transportation and enzyme production. In fact, more than 10,000 different proteins are found in the body. Protein use increases during exercise as it is broken down via gluconeogenesis in the liver to maintain the blood glucose.

Daily Requirements

The current recommended dietary allowance (RDA) is 0.8 gram/kilogram (g/kg) of body weight daily, accounting for 10% to 35% of the total energy. In the athletic population, an attempt is made to calculate the potential increases in protein requirements based on increased metabolic demand. Endurance and resistance exercise are most likely to potentially result in increased protein requirements, and many endurance athletes increase protein intake to 1.2 to 1.4 g kg^{-1} day^{-1} to support nitrogen balance. Branched-chain amino acids (BCAA), including leucine, isoleucine, and valine, are the primary protein energy source for endurance athletes. High-intensity strength training may increase protein requirements by up to 1.7 g kg^{-1} day^{-1}.

Protein as a Source of Energy

One gram of protein supplies 4 kilocalories (kcal; 1 kcal = 4,184 joules [J]) of energy, similar to carbohydrates. However, protein generally provides less than 5% of the energy expended during light exercise and activities of daily living. Basic energy requirements (BER) include the basal metabolic rate (BMR) and general activities of daily living. BER is approximately 1.3 cal/kg (1 cal = 4.18 J) of total body weight per hour. Extra energy requirements (EER) are the calories required above the BER to maintain a neutral energy balance. An average of 8.5 cal/kg of total body weight per hour of training is a gross estimation. Actual EER calories can vary greatly, depending on the individual

BMR and the intensity of the exercise. Opinions differ widely with regard to the recommended amount of EER calories that should come from protein, and they likely should vary among individual athletes. If the amount of protein is controlled in the diet, then much of the EER calories will likely come from a carbohydrate source, which is better used as an energy substrate during prolonged and strenuous exercise.

Effects on Sports Performance

Studies have shown that protein and amino acids consumed around the time strength and endurance exercises are performed can both maintain and potentially increase skeletal muscle mass. However, protein and amino acid supplementations have not proven to enhance overall athletic performance. It is also known that high-quality proteins such as soy, casein, and whey are effective in skeletal muscle synthesis and repair. Protein quality is determined by amino acid composition and digestibility. Amino acid composition in plant versus animal proteins is quite different, primarily based on the concentration of essential amino acids, which are necessary for growth and repair. Animal protein foods are called complete, high-quality proteins because they contain all the nine essential amino acids. Plant-based foods are incomplete proteins because they lack one or more of these essential amino acids. Soybean products are essentially equivalent to animal protein and only lack methionine. They are an important dietary protein source, especially in a restrictive vegetarian.

Optimum Timing of Protein Intake

The timing of protein intake has been studied in an attempt to optimize training and recovery from exercise. Protein intake should be spread throughout the day. This allows the body an opportunity to use the necessary amino acids throughout the day rather than convert them to fat. Protein ingested shortly before workouts may lead to gastric upset in some individuals. It also may serve as exercise fuel and in small amounts may have a muscle-sparing effect pre-exercise when added to carbohydrates in small amounts, similar to postexercise recovery recommendations.

Dietary Sources of Protein

There are a wide variety of natural dietary sources of protein, some of which can be used to supplement other dietary foods to increase the overall protein intake for athletes. There are four forms in which amino acids may be introduced into circulation: (1) whole-food proteins, (2) intact protein supplements, (3) free-form amino acids, and (4) protein hydrolysates. Protein can be hydrolyzed, producing small amino acid chains called peptides, which are protein forms that are easily digested. Several studies have shown that protein hydrolysates, containing mostly di- and tripeptides, are absorbed more rapidly than free-form amino acids or intact proteins. There is also recent evidence that protein hydrolysate ingestion has a strong insulinotropic effect. Thus, sports drinks containing protein hydrolysates may be beneficial in postexercise muscle recovery but cannot be consumed in unlimited amounts even in the setting of exercise-related dehydration. The American Academy of Pediatrics (AAP) recommends that health care providers strongly discourage commercial protein supplementation in adolescent and young athletes. These commercial protein supplements are largely unregulated and may contain widely varied amounts of the reported ingredients. They may also contain potentially harmful impurities. In all athletes, regardless of age, commercial protein supplementation is not better than increasing the dietary sources of protein (see Table 1). One example of increasing dietary protein is to add ¼ cup of nonfat dry milk (11 g of protein) to milk, fruit smoothies, cereal, pasta, soup, or sauce. Protein shakes can be made using milk and instant breakfast packets.

Isn't More Protein Better Than Less?

Excessive protein intake is unnecessary and even potentially harmful to an athlete's health. This is of particular importance in athletes who seek to consume protein supplements as ergogenic aids. High-protein dietary intake can compromise carbohydrate status and contribute to dehydration, weight gain, kidney and liver stress, and urinary loss of calcium due to the need for up to seven times more water to metabolize the protein. Furthermore, protein taken in excess of the daily requirement does not significantly enhance muscle gains or improve sports performance. Instead,

Table 1 Common Sources of Dietary Protein

Food	*Amount*	*Protein (g)*
Fish	3 oz	21
Chicken	3 oz	21
Turkey	3 oz	21
Red/white meat	3 oz	21
Milk	8 oz	8
Eggs	2 large	13
Tofu	3 oz	21
Peanut butter	2 tbsp	8
Yogurt	8 oz	8
Cheese	3 oz	21

Note: 1 ounce (oz) = 28.35 grams (g).

excess protein is likely to be metabolized into fat stores. Protein synthesis, even in weight lifters, seems to be most effective when protein consumption is 1.4 g kg^{-1} day^{-1}. Therefore, a calculation based on grams per kilogram per day is better than calculating percentages of protein, carbohydrate, and fat for athletes whose total caloric intake exceeds 2,000 to 2,500 kcal/day.

Table 2 provides a sample protein calculation for a 70-kg male.

Carbohydrate Plus Protein Speeds Recovery

Combining protein (AA) with carbohydrate (CHO) in the postexercise meal consumed within 2 hours of cessation of exercise nearly doubles the insulin response. As a result, a significantly larger amount of glycogen stores are replenished. The ideal carbohydrate to protein ratio is 4:1 g. Excessive protein intake postexercise can slow glycogen replacement and rehydration. Protein intake provides the necessary amino acids to rebuild the muscle broken down during intense exercise and improves muscle hydration. Consumption of CHO + AA postexercise improves postexercise recovery, thus preventing a decline in endurance performance during the heavy bouts of exercise on the following day. What research has failed to demonstrate is an actual improvement in exercise performance in endurance athletes following protein or CHO + AA supplementation. Thus, the optimal intake of carbohydrate/protein quantities is likely to be individual and is affected by personal tolerance, dietary practices, metabolism, and exercise type as well as duration. Further research is needed to establish optimal carbohydrate/protein types, amounts, and timing with regard to specific types of exercise.

Conclusion

Protein is an essential part of an athlete's diet. However, it is not a primary energy source. Even for strength and endurance athletes, limits on daily

Table 2 Sample Protein Calculation for a 70-kg Male

Daily kcal	*Protein (%)*	*kcal/day*	*Protein (g/day)*	*Protein ($g\ kg^{-1}\ day^{-1}$)*
2,000	10	200	50	0.7
2,000	15	300	75	1.1
2,000	30	600	125	1.8
4,000	10–15	400–600	100–125	1.4–1.8
5,000	10–15	500–750	125–187.5	1.8–2.7[a]
5,000	30	1,500	375	5.35[a]

Note: 1 calorie (cal) = 4.186 joules. g = gram; kcal = kilocalorie; kg = kilogram.

a. Exceeds the daily maximum of 1.7 g kg^{-1} day^{-1}.

dietary protein intake are necessary and should be calculated as percentages of total caloric intake. Protein ingestion should be spread throughout the day. A wide variety of natural protein sources exist. Commercial protein supplementation should be used with caution and strictly avoided in adolescent athletes. Consumption of CHO + AA postexercise improves postexercise recovery and is likely to be of particular benefit to endurance athletes. Further research is needed to evaluate the effects of protein intake on exercise performance, recovery, and overall health in the athletic population.

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See also Calcium in the Athlete's Diet; Carbohydrates in the Athlete's Diet; Fat in the Athlete's Diet; Nutrition and Hydration; Postgame Meal; Pregame Meal; Salt in the Athlete's Diet; Sports Drinks; Vegetarianism and Exercise; Weight Loss for Sports; Weight Gain for Sports

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Proximal Hamstring Syndrome

Proximal hamstring syndrome is a nerve entrapment disorder that occurs just below the origin of the hamstring muscles on the ischial tuberosity (the lowest part of the bony pelvis). It is characterized by pain in the buttock and the back of the thigh that typically radiates toward the back of the knee. The cause is usually fibrous bands of scar tissue around the upper hamstring muscles, which constrict and irritate the sciatic nerve. In many patients, proximal hamstring syndrome improves on its own without surgery. In patients who continue to have pain, surgical release of the fibrous bands can often resolve the problem.

Anatomy

The term *hamstrings* refers to a group of muscles in the back of the thigh that perform the same function—bending the knee and, to a lesser extent, extending the hip. The hamstrings are usually considered to include three muscles: (1) the semitendinosus, (2) the semimembranosus, and (3) the biceps femoris. Two other muscles—the sartorius and gracilis—are also technically considered hamstrings because their actions include bending the knee. They have a different action at the hip joint, however, and they are much weaker than the three primary hamstring muscles.

The ischial tuberosity is the bony part of the pelvis that you sit on. The semitendinosus and biceps femoris share a common origin on the pelvis at the ischial tuberosity. In other words, the two muscles begin as a single tendon (a ropelike connection of muscle to bone). They then split into two separate muscles as they progress down the back of the thigh. The semitendinosus travels to the inner (medial) aspect of the tibia (leg bone), while the biceps femoris travels to the outer (lateral) aspect of the tibia and fibula. The semimembranosus runs deep to the semitendinosus from its origin on the ischial tuberosity to its multiple insertions at the back of the knee. The sciatic nerve is the nerve that innervates the muscles of the lower leg. The sciatic nerve exits the pelvis and passes just lateral to the origin of the semitendinosus and biceps femoris muscles. The nerve then passes beneath the biceps femoris muscle as it runs to its connection at the back of the knee. The gluteus maximus is the large buttock muscle that covers the upper part of all these structures. The hamstrings emerge from under the gluteus maximus about 3 inches (in.; 1 in. = 2.54 centimeters) below the ischial tuberosity.

Etiology

Proximal hamstring syndrome most commonly occurs in high-level athletes, especially sprinters and hurdlers. It is relatively rare, and there are few published reports describing its symptoms. Proximal hamstring syndrome is thought to be associated with prior hamstring strains. A strain occurs when a muscle overstretches, which tears some of the muscle fibers. These strains can range from minor injuries to complete ruptures of the entire muscle. As the muscle attempts to repair the strain, it can form thick, fibrous bands of scar tissue.

Hamstring strains in particular are extremely common sports-related injuries at all levels of participation. The most commonly injured muscle is the biceps femoris, and the most common location of injury is the upper junction between the muscle and the single tendon. This location is exactly where the sciatic nerve dives underneath the biceps femoris muscle to travel down the rest of the posterior thigh. It is thought that scarring in this area from prior hamstring strain injuries can entrap and compress the sciatic nerve. This leads to pain in the buttock area and can cause referred pain to other sites innervated by the sciatic nerve.

Symptoms

Patients typically complain of pain in the buttock region that radiates down the back of the thigh or even lower into the leg. It is usually exacerbated by activities that put pressure on that area, such as sitting or driving, or activities that stretch the nerve, such as performing hamstring stretches. Athletes will often complain of pain when fully using the hamstrings for rigorous activity, such as speeding up to a sprint or kicking a ball forcefully. Changing the position or stopping the offending activity usually relieves the pain.

Physical Exam

Generally, there is localized tenderness over the ischial tuberosity. It may be possible to palpate the tight bands of scar tissue in the biceps femoris muscle, although this is not a reliable finding. Having the patient perform a hamstring stretch will usually reproduce the symptoms. However, the typical straight leg raise test, which is helpful for diagnosing sciatica, is usually negative in proximal hamstring syndrome. The patient's neurologic exam is usually normal, and electrical nerve and muscle studies can be normal as well.

Diagnosis

Proximal hamstring syndrome is a clinical diagnosis. However, after seeing a patient with signs and symptoms of proximal hamstring syndrome, several other diagnoses should be considered. Plain X-rays of the area should be taken to rule out a growth plate avulsion fracture of the pelvis, especially in adolescents. In addition, a magnetic resonance imaging (MRI) scan of the lumbar spine should be obtained to rule out a herniated disk or lumbar spinal stenosis (narrowing of the spine causing nerve impingement). Another important diagnosis to exclude is piriformis syndrome, in which the sciatic nerve is compressed under the piriformis muscle (see the entry Piriformis Syndrome). In this condition, the patient's pain is usually located more proximal (higher up) than the buttock pain of proximal hamstring syndrome. Helpful physical exam maneuvers to diagnose piriformis syndrome include the *Pace sign* (pain with resisted hip abduction and thigh external rotation) and the *Freiberg sign* (pain with forced internal rotation of the extended thigh). Other diagnoses to consider are *ischiogluteal bursitis* (pain in the buttock that is usually constant and does not change with activity or position) and *chronic exertional compartment syndrome* (pain occurs only when exercising; stretching or sitting usually does not elicit pain).

Nonoperative Treatment

As with most hamstring problems, the first-line treatment for proximal hamstring syndrome does not involve surgery. The mainstay of conservative treatment for most muscle injuries remains the RICE protocol (*r*est, *i*ce, *c*ompress, and *e*levate). However, given the long healing times for most hamstring strains (3 to 6 weeks or more), many other treatment protocols have been devised. These range from stretching programs and posture and trunk control training to other modalities such as electrical stimulation and deep tissue massage. There are no published randomized control trials comparing any of these treatment modalities with rest, so their efficacy is unclear. In addition, there are no published data of any kind evaluating the nonoperative treatment of proximal hamstring syndrome. Theoretically, the treatments designed to help muscle strains should also help heal the scarring in proximal hamstring syndrome. Therefore, most sports medicine physicians recommend an extensive trial of some or all of the above conservative measures before resorting to surgery.

Operative Treatment

Once the diagnosis is established and the patient has failed a prolonged course of conservative measures, it is reasonable to consider operative intervention. Patients should be counseled that this involves a large incision, typically over the buttock region. The sciatic nerve is identified deep in the buttock, and any scar tissue around it is released. Some surgeons will then cover the nerve with a special, skin-derived tissue to try to prevent the scar from re-forming. The primary risk of the operation is injury to the sciatic nerve as it is dissected free from the fibrous bands of scar tissue. Any minor injury to the nerve generally resolves after 6 to 12 months, but more severe injuries can result in permanent severe leg weakness, numbness, muscle wasting, and foot drop. In the only published operative case series, 52 of 59 patients had resolution of their symptoms after surgery. Seven failed to improve well enough to return to sports. Two patients had wound complications, and 2 patients had numbness on the thigh from cutaneous nerve damage. Five patients took more than 6 months to improve but ultimately did have resolution of their symptoms.

After Surgery

Crutches are typically used until the patient is able to walk comfortably on the affected leg. As soon as the skin incision heals (in about 2 weeks), physical therapy is begun. At first, this usually consists of gentle hamstring stretching, which then advances to more rigorous motion. The principle behind physical therapy is to use motion to prevent the formation of more scar tissue, while avoiding being overaggressive to prevent reinjury to the muscle or nerve.

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See also Hamstring Strain; Pelvic Avulsion Fractures; Piriformis Syndrome; Sciatica

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Proximal Interphalangeal Joint Dislocation

The most frequently injured joint in sports is the proximal interphalangeal (PIP) joint, with dislocations at this site being more common than in any other joint in the body. PIP joint dislocations can be anatomically divided into dorsal, volar, or lateral. Dorsal dislocations are the most common. Athletes participating in sports involving manual ball contact, such as football and basketball, experience the highest rates of PIP injuries.

The hinge joint configuration allows flexion and extension only. Each finger joint consists of a fibrous capsule lined by a synovial membrane, two collateral ligaments, and a volar plate. Both the volar plate and the collateral ligaments protect against hyperextension; the latter also resists lateral dislocation, while the former hinders dorsal dislocation. Hyperflexion and volar displacement are prevented by the stabilizing extensor hood complex.

Dorsal dislocations are the most common and refer to dorsal displacement of the middle phalanx relative to the proximal phalanx. The more rare volar dislocation signifies an anterolateral displacement of the middle phalanx relative to the proximal phalanx head. Lateral dislocations involve a partial or complete tear of the collateral ligament complex.

History and Physical Exam

Because injuries to the hand are common, athletes may initially disregard PIP trauma as simply a "jammed" finger and delay seeking medical attention. A thorough assessment and accurate diagnosis are important first steps to avoid chronic defects and disability. The history of injury should include the setting of injury, specifically the sports, position, and mechanism. Next, a typical pain assessment should uncover both the immediate and the persistent symptoms, including any change in this pattern over time. Typically, the athlete will describe pain, swelling, and paresthesias over the affected joint. Ultimately, the information most likely to lead to diagnosis is a description of dysfunction, what the player can and cannot do since the injury occurred.

A thorough physical exam of the entire upper extremity on both the injured and the uninjured side is ideal. When focusing on the PIP joint, inspection of the hand in the relaxed and clenched positions may help reveal any deformity. Certain acute PIP dislocations may result in characteristic phalanx deformities, such as swan-neck and boutonniere. The swan-neck deformity occurs when the PIP joint is hyperextended and the distal interphalangeal (DIP) joint is flexed, while the boutonniere deformity is the opposite, occurring with flexion of the PIP and extension of the DIP, a result of avulsion at the extensor digitorum communis tendon.

Normal range of motion at the PIP joint is 100° of flexion and 0° of extension. Accurate assessment relies on isolating the joint by holding the DIP just distal to the site being examined. Tenderness, swelling, and weakness over the affected PIP joint are common. Rupture of a tendon, ligament, or intraarticular fragment can manifest as limitation in active and resisted flexion and extension. Perform passive hyperextension to determine volar plate integrity, and apply varus and valgus stress to assess the collateral ligaments. The Elson test evaluates for rupture of the extensor tendon central slip at the base of the proximal phalanx, which leads to the boutonniere deformity mentioned above. With the finger over the edge of a table and the PIP joint at 90°, a positive test yields weakness against resisted extension and hyperextension of the DIP. A neurovascular exam of the finger is an essential part of the complete exam.

Imaging Tests

Anteroposterior, lateral, and oblique radiographs of the entire finger should be obtained prior to and after treatment to both confirm the diagnosis and exclude a related fracture. A true lateral view causes the condyles of the proximal phalanx head to be superimposed and allows for detection of otherwise subtle irregularities. Stress views may be used to determine joint stability. One caution when interpreting radiographs is that the nutrient arteries of the proximal phalanx distal condyles can appear as undisplaced fractures.

Dorsal Dislocation

Mechanism

Dorsal PIP joint dislocations typically occur when an act of hyperextension stress is combined with axial loading. This action disrupts the volar plate from its distal attachment, along with at least one collateral ligament. The resulting volar plate rupture may occur with or without an avulsion fracture of the base of the middle phalanx. The volar plate remains attached proximally to the proximal phalanx and laterally to the accessory collateral ligament. Injuries can be categorized as hyperextension injury (Type I), dorsal dislocations (Type II), and fracture dislocations (Type III).

Treatment

The goals of treatment are to promote healing of the volar plate, joint capsule, and collateral ligaments with the goal of restoring normal joint function.

However, in practice, reduction often occurs immediately on the playing field or sideline. In fact, dorsal dislocations are often referred to as "coaches' finger" because of the tendency of coaches, or the athletes themselves, to perform the reduction.

Reduction involves first freeing the middle phalanx by gently hyperextending the PIP. Then, while exerting gentle axial traction, flex the middle phalanx until it reduces. Following reduction, examine the joint for local tenderness, range of motion, and tendon function. Also examine to detect instability in the dorsal-volar and medial-lateral directions. Radiographs must be obtained after reduction to confirm proper alignment.

Most dislocations are stable and can then be immobilized by splinting with 20° to 30° of flexion for 2 to 3 weeks in a dorsal block splint. Following this period of immobilization, an active flexion program with buddy tapping can be initiated. Supplementary therapy with ice, nonsteroidal anti-inflammatory drugs (NSAIDs), and elevation can treat the accompanying pain and inflammation.

Dorsal dislocations involving fracture are considered stable if less than 40% of the joint surface is affected and unstable if the fracture fragment is greater. Injuries with fracture can be treated with a trial of closed reduction by placing the joint in 75° of flexion and reducing the amount over 4 to 5 weeks. In some cases, open reduction and internal fixation are required.

Complications

An untreated dorsal dislocation may result in hyperextension deformity and chronic instability from laxity of the volar plate. Compensatory changes in a chronically dislocated PIP joint can lead to a swan-neck deformity. The ultimate function and appearance of the joint can also be compromised by nonunion of a fracture at this site.

Despite early reduction, pain and swelling often persist for weeks to months following the injury. Other complications following appropriate treatment include recurrent dislocation, resulting from inadequate immobilization, and muscle contraction following prolonged splinting.

Return to Sports

The issue of return to play (RTP) must take into account the individual athlete, the dominant hand, the degree of injury, and the specific sport or position played. In general, athletes with simple dorsal dislocations may return to sports as tolerated only with protective immobilization. When fractures are involved or open reduction is required, RTP will be more prolonged and may take up to 8 weeks before activity with buddy taping is permitted. Complete resolution of symptoms may not occur for 6 to 8 months.

Volar Dislocation

Mechanism

Volar PIP joint dislocations result from the combination of either valgus or varus force with an action of volar thrust to the middle phalanx. This compressive and rotatory motion can cause injury to the central slip, collateral ligaments, and volar plate. The resulting dislocation can be either a volar dislocation or a volar rotatory subluxation, involving rotation about one intact collateral ligament. A rare volar fracture dislocation can also occur from a similar mechanism.

Imaging Tests

As with dorsal dislocations, radiographs (anterior-posterior, lateral, and oblique) ideally should be obtained prior to and following an attempted reduction.

Treatment

Although volar PIP joint dislocations are uncommon, they often require more involved intervention because of instability and resistance to closed reduction. The inability to reduce can result from soft tissue or bone interposing the joint. The recommendation is to attempt reduction by holding the metacarpophalangeal (MP) and proximal interphalangeal (PIP) joints in flexed position while applying gentle traction with the idea of relaxing the displaced lateral band and allowing the intraarticular portion to be disengaged. However, some cases will require orthopedic referral for possible open reduction and internal fixation.

Depending on the method of reduction and the specific type of injury, immobilization in extension may be required for 6 weeks.

Complications

Chronic volar dislocations can lead to boutonniere deformity as described above. Obtaining full function is difficult with delayed surgery.

Return to Sports

The PIP needs to remain in extension with this dislocation for 6 weeks. Because surgical correction may be required, the time period before RTP will be longer (up to 12 weeks) in volar dislocations.

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See also Finger Dislocation; Finger Fractures: Bennett Fracture, Boxer's Fracture; Finger Fractures: Overview; Finger Sprain; Hand and Finger Injuries; Hand and Finger Injuries, Surgery for; Jersey Finger; Mallet Finger; Trigger Finger

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Psychological Aspects of Injury and Rehabilitation

Athletes, whether world class or sandlot, incur psychological trauma when they sustain physical injury. While this might seem obvious if there is a financial concern, as with a professional ballplayer or high school prospect aiming for a scholarship, the issue is no less real for recreational athletes, including *senior* or *masters athletes*. Importantly, how one responds to this psychological stress can determine one's commitment to therapy and, thus, the possible return to pre-injury or presurgical fitness. Moreover, it is important for older patients to remain active for optimal long-term physical and mental health. Most doctors, therapists, and athletic trainers excel at the physical aspects of treating injuries, but it is also important for these caregivers to appreciate the psychological influence of injury and rehabilitation.

The American Orthopaedic Society for Sports Medicine (AOSSM) released a Consensus Statement in 2006 describing what they believed was important sport psychology knowledge for team doctors, many of whom are orthopedic surgeons. Included in this statement was language indicating that the team doctor should have knowledge regarding the psychological aspects of the antecedents of athletic injury. Additionally, the team physician should be well versed in the psychological issues accompanying injury, rehabilitation, and return to play. Finally, they recommended that team doctors be aware of the mental health resources in their area. These conclusions were seconded in an article describing the results of a survey taken with a range of sports medicine providers, including orthopedic surgeons, physiatrists, osteopaths, and primary care sports medicine doctors. Unfortunately, and consistent with long-held stereotypes, the results of this survey noted that orthopedic surgeons, the doctors who are most often designated team physicians, were comparatively the worst specialty for discussing emotional and behavioral issues with their patient-athletes. This section will attempt to serve as an introduction toward a remedy for these deficiencies.

Response to Injury

A large segment of sport psychology is devoted to the concept of harnessing the brain for performance enhancement, most famously in athletes. When injury is thrown into this cauldron of athletic performance, the psychological stress added to the physical stress often marks the end of an athletic career, or at least a diminution in effectiveness. In one recent study from the National Football League, only two out of three running and defensive backs returned to a similar level of play after an anterior cruciate ligament (ACL) injury. While one knee cannot be compared exactly with another knee, this study begs the question of why, once an ACL is reconstructed, there is such a discrepancy in this group's recovery. One question that might be considered when returning from injury is, Are we rehabilitating a limb injury or a "brain" injury? In other words, is the athlete struggling with achieving his or her rehab goals because of physical issues, or is he or she limited due to (often appropriate) psychological issues?

It is perfectly reasonable for an athlete to feel trepidation when returning to a dangerous sport; in fact, it is hardwired in our sympathetic nervous system. When competing on the athletic field in most sports, we are putting ourselves in harm's way and must fight our primitive brain on some level to accomplish this task effectively. Those who can "sacrifice their bodies" and "play through pain" are coveted by teammates and coaches. This fight with our primitive (and cognitive) brain is especially heightened when returning from the recent pain and disability of injury or surgery. The athlete now must wrestle with his or her brain's awareness of the "bad knee" or surgically reconstructed shoulder. This presents a significant challenge of confidence for any patient, especially for those competing in high-risk sports.

As caregivers, by addressing the "whole athlete," we will gain insight into how athletes appraise their injury, how motivated they will be in the recovery process, how they will deal with setbacks, and how they might negotiate the fear of possible reinjury. While the recovery from physical injury generally follows a physiologic path,

Injury → Healing → Rehabilitation →
Gradual Return to Sports,

psychological recovery might not proceed in such a stepwise fashion. Those with athletic backgrounds, however, tend to do better with rehab and coping postinjury than do nonathletes. Having each patient assessed by a sports psychologist is ideal but not especially practical. A baseline sport psychology evaluation should be the norm, however, for high-level athletes. Similar to neurocognitive studies, which are now administered to assess return from head injury, sport psychology data should be obtained in serious athletes pre-injury to establish a baseline and, subsequently, postinjury to assess any potential issues.

One parameter that can help assess how an athlete responds psychologically to an injury is the importance of athletics in that person's life. This is often referred to as *athletic identity,* or the degree to which an individual identifies with the athlete's role, which can remain throughout a lifetime. Such evaluations are influenced by past achievements, family, friends, and no doubt certain intrinsic motivations. Having a strong athletic identity is thought to help patients continue to participate in some type of physical activity in old age. Those patients with high athletic identities, however, will be more prone to depression after sustaining a significant injury. Also important to note for those of us treating masters athletes is that simply getting old does not change this attitude! After injury and illness, along with the blow to athletic identity comes possible mood disturbance, lowered self-esteem, diminished self-efficacy, and, in some cases, the first inklings of mortality.

Psychological Injury Models

A number of models have been developed that discuss both the response to and the prediction of athletic injury. This includes the death-and-dying model of Elisabeth Kübler-Ross as it might pertain to athletic trauma. Though these models can be interesting from a research standpoint and for their long-term implications, they can be difficult to relate to in a busy sports medicine practice. Gould and colleagues, in their article "Coping With Season-Ending Injuries" (1997), describe various stress sources that athletes might have to deal with when recovering from injury. They describe three major aspects of this stress, including (1) a "major life event change," referring to the loss of one's career and paycheck; (2) "chronic stress," both physical and psychological, due to one's injury; and (3) "daily hassles" due to physical immobility. All these stress sources, barring the monetary issue, are a huge part of the psychology of everyone who identifies himself or herself as an athlete on any level. Thus, in addition to the professional athlete, the stresses of injury are also true for older athletes who are retired from work and whose children have left home. For elderly patients, their activities, whether they are competitive, social, or simply hiking in the woods with their dog, are a major part of their health situation, and for many, they treat them essentially as a second career. They cannot (and should not) give them up easily. Active elders are often one significant injury or illness away from true disability. This fact is not lost on these patients and will often add to the psychological stress.

Heil, in his article "Sport Psychology, the Athlete at Risk, and the Sports Medicine Team" (1993), describes a cyclical response to injury as opposed to progressive acceptance through stages. He breaks down the response to injury as *distress, denial,* and *determined coping*. Distress is the effect the injury has on one's emotional equilibrium, denial is unacknowledged distress, and determined coping involves using knowledge, skills, and energy to move beyond and recover from the injury. Of course, not all athletes respond to injury in a similar fashion, as this will depend on many factors, such as maturity level and what career stage they are in. As noted by Britton W. Brewer, it is not necessarily how the injury occurs but how it is perceived and appraised. Brewer includes in his model personal variables such as psychological involvement in sports, self-esteem, and age.

Andersen and Williams, in their article "A Model of Stress and Athletic Injury: Prediction and Prevention" (1988), based on a seminal study conducted more than two decades ago, discuss the connection between stress and injury and offer possible interventions to decrease these connections. Their interactional, theoretical model takes into account aspects of life that could lead to injury, including cognitive, attentional, behavioral, intrapersonal, social, and general stress factors. Problems with any of these factors could potentially result in changing focus, muscle tension, distractibility, and so on. These concepts have been supported by other studies in collegiate athletes engaged in multiple sports. The article by Hanson et al. titled "The Relationship of Personality Characteristics, Life Stress, and Coping Resources to Athletic Injury" (1992) equates the severity of injury with the amount of negative life stress. While many of these models are individualized, they are still too cumbersome for routine use. Sports psychologists must develop quantitative/user-friendly tools that general sports medicine providers can employ to help their patients return from injury.

One such program that attempts to simplify and combine physical and psychological rehab is that of O'Neill. He asks athletes to equate their "rehabilitation program" with their pre-injury "training program" by quantifying activities into a "three-pronged attack" of exercise, sport-specific movement patterns, and aerobic training. By involving the athlete in a program he or she can understand in a physiologic sense, as well as introducing simple sport psychology principles immediately, this program attempts to bring the mind and body together in recovery. The patient is asked not to think of rehabilitation in stages that only focus on the injury but to begin working on specific doable sports skills that need improvement, as well as other possible physiologic and psychological weaknesses. The period of rehabilitation from injury can be a time for coaching that can effect positive changes in certain skills and muscle qualities in areas away from the injury. Physiologic issues such as core strength and flexibility or very specific skills, such as serve toss, putting, foul shooting, and so on, can be evaluated, and bad habits can potentially be eliminated while recovering from, for example, a meniscus tear. A positive cycle of improvements in physiology, followed by improvements in psychology, followed by improvements in physiology, and so on, can then be developed.

Quantifying Sport Psychology

Yogi Berra famously said, "Baseball is 90% mental, and the other half is physical." Although this was said more than 50 years ago, the elusive "mind-body connection" has proven difficult to achieve consistently, except in the most remarkable of athletes. Is avoiding undue risk and injury a skill that can be taught? Are we able to teach self-awareness? Do both the primitive and the cognitive brain shut down to risk in certain athletes? Sport psychology is still in its infancy in attempting to answer these questions and to help make the mind-body connection available to everyone.

While patients will often respond to injury with mood disturbances and decreased self-esteem, it is difficult to know to what extent they will do so. In addition to those involved with the care of patients having "their antenna up" for adjustment issues, psychometric testing is another way to quantify how the patient is doing psychologically. Psychometric testing is attempting to measure emotions and feelings by having the patient complete questionnaires. Due to this individualized method of eliciting information, these tools are subjective evaluations and are thus often weakened by reporter bias. Despite the potential weaknesses, many sports psychologists will obtain baseline psychometric data and repeat testing on a periodic basis. There are many tests available depending on the population being cared for. In the orthopedic literature, SF-36 is presently the most commonly sited health survey for adult patients as it includes both general and psychological health information.

In addition to psychometric testing, another way to make psychological issues more quantitative and get answers to these questions is through biofeedback. Biofeedback can be thought of as teaching people to improve health and performance by observing the physiologic signals generated from their bodies in "real time." Physiologic signals such as the electroencephalogram (EEG), electromyogram (EMG), skin conductance (sweating), respiration, blood pressure, temperature, and the like can all be measured and "fed back" to the subject. Using this information, the athlete can more rapidly improve on problematic issues, including stress response, arousal, relaxation, exercise tolerance, and so on. With new computer technology and mobile monitoring, biofeedback is not limited to the laboratory but can be taken onto the field, the golf course, and the ski jump hill. One of the more exciting aspects of biofeedback is its use to quantify coping and recovery, and thus, it may have a role in injury prevention (see the entry Biofeedback).

Sports Psychology Skills

When we discuss sport psychology with noninjured players, we often speak of a litany of techniques now familiar to most athletes, including goal setting, coping, self-talk, arousal, relaxation, and so on. This same skill set should be employed by athletes (or nonathletes) returning from injury. Athletes tend to do better in rehab as they can use such skills, their natural determination, and physical muscle memory to get better faster. In addition to these extrinsic factors, intrinsic factors such as optimism, hardiness, and global self-esteem will play a role in recovering from injury.

It is normal and often functional to have fear after injury, and in fact the patient will often show symptoms similar to posttraumatic stress disorder. Some coaches famously ignore injured athletes, because they see the attention as a sign of weakness or because of concerns about a possible "injury contagion" phenomenon. While this might be acceptable in professional sports, it should not be the rule at the lower levels. We should try to have the athlete returning from injury in full view of the coaches and teammates, for the purposes of both coaching and other social aspects of team participation. Parents, coaches, trainers, doctors, friends, and teammates are all important components of the support system for a healthy psychological response in the face of a physical setback.

The Role of the Sports Medicine Doctor

There are huge differences between professional and recreational athletes on the field, but when it comes to injuries, there are many similarities. No matter what the patient-athletes' age or competition level, once an injury occurs, numerous questions should be asked that will be important to their recovery. What are their coping mechanisms? How is their time structured regarding work, family, and athletics? What kind of social support do they have? What do they see as alternatives to their previous activities while they are recovering or, in the worst case scenario, if they never recover? For professional athletes returning from injury, coping mechanisms, time management, and social support are very important. Conversely, many nonprofessionals are using athletics *for* coping, time management, and social support. When nonprofessionals are injured and cannot attend ski races, triathlons, or lawn bowling matches, it can create an equally significant void in their lives. Coping can be defined on many fronts, but the most common definition used by sports psychologists is that of "a process of constantly changing cognitive and behavioral efforts to manage specific external and/or internal demands or conflicts appraised as taxing or exceeding one's resources." Sports medicine doctors should be a part of the coping mechanism to help patients through these potentially difficult periods. Part of this approach would be to recommend new outlets for the athlete's competitive and emotional needs, as well as suggesting safe physical venues for training and rehab. Many of these folks will not respond to psychological support without a physical outlet. A well-functioning sports medicine clinic will employ like-minded physical therapists, trainers, and ideally a sports psychologist to create a true rehab *team* to participate in the patient's care.

Of the psychological skills listed above, apart from coping, perhaps the next most important skill while recovering from injury is the use of goal setting. Major injuries will lead to the loss of many "ego" goals, such as the scoring record, the picture in the newspaper, perhaps even a scholarship. As a result, we try to focus the patient on "task-oriented" goals—goals that are concerned with daily and weekly improvement, moving toward full recovery. By establishing specific task goals, not only will the athletes improve physically, but also the quantitative improvement they see (though it might seem glacial) will lead to improved rehab adherence. Getting the athlete on board with a systematic program will give him or her confidence in rehabilitation and, subsequently, confidence in returning to competition. Such goals must be realistic and should build daily toward the long-term goal of full athletic involvement.

Perhaps one problem with asking medical and surgical doctors to address the psychological needs of their patients is not only time but also background. Athletic trainers, physical therapists, coaches, and friends have all been deemed more important outlets and confidants for athletes' emotional issues while recovering from injury than the team physician. This is despite the fact that these other caregivers often have equally little formal training to help with such problems. Ideally, the physician or other members of the medical rehab team will recognize the patient who needs extra support after an injury and can designate time to address such issues. Again, everyone involved with the care of patient-athletes should have some understanding of their psychological traumas, if for no other reason than to know when to refer them to a mental health provider. Signs of such psychological trauma and possible problematic adjustment to injury include, but of course are not limited to, depression, mood swings, apathy, obsession with playing again, denial of the significance of the injury, guilt for "letting the team down," dependence on caregivers, and quitting. Remember, many recreational athletes use athletics for coping—when this outlet is no longer available, they will sometimes use socially unacceptable or unhealthy mechanisms for stress relief. In an unpublished study, we found that Division III athletes had a decrease in grades after a season-ending injury—contrary to what one might expect with the increased time thus available for study.

In conclusion, our goal as sports medicine providers is to return athletes to the field after appropriate rehabilitation, both physical and mental. While we might not be able to guarantee a new, improved body, we might be able to achieve a new, improved mentality. What we should attempt as sports medicine providers who treat the whole athlete is to help make the athletes *smarter* even in light of potentially less than perfect physiology. Try to get the brain involved to appreciate what the athletes can and cannot do physically, as well as what they had done previously and also what they might do better. This should be thought of as *physical* sport psychology. In the sport psychology of returning from injury, we are dealing not just with the emotional issues related to the injury but with the actual physiologic changes that must be accounted for to allow complete recovery. To be most effective, this approach requires assessing not just the strength of the injured limb but the full spectrum of physical, mental, and emotional trauma. By using a rehab team, we believe, full recovery can be accomplished in an efficient manner and, ultimately, the athlete can be readied for a safer return to the field of play.

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See also Anger and Violence in Sports; Arousal and Athletic Performance; Attention Focus in Sports; Biofeedback; Exercise Addiction/Overactivity Disorders; Hypnosis and Sports Performance; Imagery and Visualization; Mental Health Benefits of Sports and Exercise; Personality and Exercise

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Psychological Assessment in Sports

Psychological assessment in sports involves the use of information sources, including psychological tests, personal and medical history, current symptoms and problems reported by either the athlete or professionals, and persons related to the athletes. Whenever an athlete seeks help from a psychologist, the first task of the sports psychologist is to determine the problem precisely. A nomothetic approach is expected in the traditional psychological assessment, which emphasizes group experimental designs, diagnosis, or classification and the use of standardized interview and psychometrics.

Assessment and intervention are phases within a psychological process in which intervention (treatment) evolves from assessment. Assessment refers to the explorative part, and intervention refers to modifying part of this integrated action sequence. Assessment includes sports psychological interviews, systematic observation of athletes, coaches' and team behavior, and sports psychological tests (questionnaires as well as computerized testing of, e.g., attention skills). It also may help identify problems.

Sports psychologists are aware of the different psychological processes of athletes. Most of the assessment instruments in sport psychology focus on individual differences (i.e., achievement orientation, concentration skills, or anxiety). An intervention in sport psychology might be useful in identifying the individual differences within a team, helping the coach better understand his or her athletes' individual behavior, and placing certain events or positions in teams.

It may be difficult to understand or distinguish all the causes and effects of the attitudes, beliefs, and behaviors of athletes during training and competition that lead to excellence of performance or the lack of it. Not only do people naturally have different personal preferences from a general psychological viewpoint (strong vs. weak personality characteristics, temperament, attributions, or ways of coping with stress and adversity), but in sports, other (sports psychological) factors may be involved as well (i.e., achievement goal orientations, sources of confidence in sports, optimal levels of arousal, competitive anxiety, or basic mental skills for control and adaptation in the sports context).

A sports psychological assessment aims to provide more clarity about the athletes' sports psychological makeup. Self-awareness is the first step to decide if appropriate follow-up is needed. The results of the assessment could help deal with future situations more effectively. Opportunities for improvement and development, thereby empowering the athlete for increasing personal well-being and the potential for performance excellence, may evolve.

For different reasons, the athlete, coach, or sports psychologist may want to assess various personal and sports psychological preferences, characteristics, or skills that may co-influence the athlete's performances or preparations for performances.

For each assessment, the sports psychologist will discuss the need with the athlete, explain the assessment process, and come to a mutual agreement through an informed consent for administration of the chosen sport's psychological assessment tool(s).

The use of appropriate assessment instruments requires clarification of the following questions:

1. What is the level of the assessment?
2. Should the assessment instrument be a general psychological measure or domain specific, or even sport specific?
3. What type of assessment data should or can be obtained? (Questionnaire data are usually the most simple and the cheapest method of obtaining information. Other types are interviews, observations, and physiological measures.)

In sport psychology practice and research, traditional forms of assessment have included the use of self-report questionnaires or inventories. Psychological assessment can be successfully integrated into competitive sports if important elements are considered and appropriately applied. Up to three fourths of sports psychological consultants are believed to use psychological inventories or survey questionnaires in their applied work with athletes.

The most formal assessment instruments are standardized tests. The more formal and standardized the assessment is, the easier it is to make interindividual comparisons and to relate the given situation to more general, theoretical knowledge in sport psychology, which might derive appropriate interventions that have proven to be successful. Formal tests are highly reliable and valid instruments. Standardized questionnaires rely on the main psychometric criteria of objectivity (the results of the test are independent from the person who provides the test), reliability (determining the level of accuracy of the measurement tool), and validity (how precisely the test can measure what it aims at measuring). The side criteria of economics (the cost of the procedure, evaluation, and general handling of the test should be as low as possible) and norms (standardized test for an economical comparison of the test scores) are important when standardized instruments are evaluated.

The testing principle needs to be understood before administering and interpreting psychological inventories. Furthermore, recognition of measurement errors and having well-designed and validated measures are important. Not all psychological tests have been systematically developed and made reliable. A prediction about the behavior and personality structure of an athlete or coach according to such tests would be misleading and unethical.

After completion of the actual assessment, all information gathered must be interpreted and translated in an understandable language. A personal, individualized report is completed, including explanations about the results and conclusions. During a feedback session, the results of the sports psychological assessment and the concluding report are discussed. The athletes' own beliefs and suggestions may be recorded and added to the report. Finally, informed consent will be established and for each (combination of) sports psychological assessment(s), an individualized and confidential report is generated and offered to the participating athlete. In the follow-up session, the results are discussed and explained.

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See also Anger and Violence in Sports; Arousal and Athletic Performance; Attention Focus in Sports; Biofeedback; Exercise Addiction/Overactivity Disorders; Hypnosis and Sport Performance; Imagery and Visualization; Mental Health Benefits of Sports and Exercise; Personality and Exercise; Psychological Aspects of Injury and Rehabilitation

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Psychology of the Young Athlete

Sport psychology not only addresses the mental skill needs of elite athletes; it also makes a significant contribution to the understanding of children in youth sports. In the United States, it is estimated that 45 million children under the age of 18 participate in school and extracurricular physical activity programs. Researchers have found that children on average spend 11 hours weekly in youth sports programs and have seasons that extend for about 18 weeks per year. For most children, sports participation peaks around the age of 12. Developmental psychology outlines in detail the periods of development leading up to this age that are critical for children's growth in self-esteem and social development through sports.

Milestone Development

Early Childhood (6–8 Years)

Sports activities for this age-group need to be tailored to the physical, cognitive, and emotional abilities of this group. These children make slow gains in height and weight until their adolescent growth spurt. Kids in this age-group start to play games with rules, and dominance in hierarchies becomes more stable and self-organizing. The cognitive markers for this age-group include thinking, becoming more logical, and a beginning of understanding of spatial concepts. Attention becomes more selective and adaptable. Children in this age-group also begin to use memory strategies of rehearsal and organization. The emotional and social characteristics of this age are marked by the beginning of the development of self-concept. This includes the ability to identify personality traits and make social comparisons. Self-esteem starts to differentiate and becomes hierarchically organized. The child starts to become realistic, and emotions of pride and guilt start to be governed by personal responsibility. Children in this age-group begin to develop the awareness that individuals can have more than one emotion and start to understand that access to different information often causes people to have different perspectives.

Middle Childhood (9–11 Years)

Organized sports activities for this age-group will build on the skills acquired in early childhood and integrate the child's growing abilities to meet the physical, cognitive, and emotional challenges presented through sports experience. Adolescent growth spurts begin on average 2 years earlier for girls than for boys. Gross motor skills of running, jumping, throwing, catching, kicking, batting, and dribbling are executed more quickly and with better coordination. Reaction time improves, contributing to overall motor skill development. Logical thought remains tied to the concrete situation until the end of middle childhood. Planning improves, and memory strategies of rehearsal and organization become more effective. Self-esteem becomes more durable, and children in this age-group begin to distinguish between ability and effort, as well as their attributions for success and failure. Child athletes in this age-group also begin to form strategies for regulating emotion, and the beginning of mental skill training in sports is possible.

Early Adolescence (11–14 Years)

Girls may have reached the peak of their growth spurt, including the beginning of menses and potential changes in body composition (adding more body fat than muscle). Boys are usually beginning their growth spurt, and changes in athletic ability as well as proneness to injury are related to change in muscle composition as rapid growth occurs. This phase of development includes the ability to become more capable cognitively of formal operation reasoning. Adolescent athletes are better able to coordinate theory with evidence, argue more effectively, and become more self-conscious and self-focused. The emotional swings of this age are well-known and understood. Moodiness and parent-child conflict increase. Adolescents define their identities through peer relationships, spend time with kids who share similar values, and organize into cliques.

Late Adolescence (14–16 Years)

Girls have mostly completed their growth spurts and may or may not have reached menses. Early competitive sports that require low body fat and composition ratios (e.g., gymnastics and figure skating) can delay growth as well as full development. Boys are still growing furiously during this age and are adding muscle while body fat declines. For most boys, this age range includes rapid increases in motor performances and sharpened athletic abilities. The cognitive gains made in early adolescence are being refined through early adulthood. Adolescents become better at planning and decision making, and there is a trailing off of self-consciousness and self-preoccupation. The emotional/social characteristics of this age-group consist of forming the self into an organized self-concept. Athletes in this age-group experience better differentiation in self-esteem. Big-picture thinking and relating become more consistent, and the ability to view things from a societal perspective increases.

Psychological Growth and Development

When exploring the psychology of the young athlete, several components of youth experience are taken into account. There are developmental considerations of both motor and cognitive abilities, motivation issues, and competitive considerations. Research shows that the main reason why young athletes participate in nonschool and school sports is "to have fun." Several gender differences emerge after the primary motivation, with boys emphasizing skill development and girls emphasizing "staying in shape." Both girls and boys rate the "challenge of competition" and "skill acquisition" among the first seven reasons. It is significant that the ongoing reasons why child athletes continue to compete in sports is because learning new skills keeps them engaged and having fun.

Before age 9, most children do not have the ability to make a distinction between effort and ability. With this inability to differentiate between the two, children do not draw conclusions that effectiveness in sports participation is related to their own abilities. If they lose, they are likely to believe that they can win if they work harder, rather than drawing a conclusion that they are not "as good" as another player. Between the ages of 9 and 11, the concepts of ability and effort begin to be distinguished. Children can start to make their own assessment of their ability and the abilities of others. By age 11 or 12, this distinction is rather clear in most children's minds. This awareness has a significant impact on their experience, participation, and drive to pursue sports activities after age 12. Understanding this awareness in children can help provide the right level of sports experience to encourage more young athletes to stay active and remain in youth sports instead of drawing conclusions about not being good enough and quitting.

Implications for Practice and Training

Maureen Weiss, a leading researcher in youth sports, concluded that the children who continue to participate in youth sports continue to perceive that they are competent in their sport. That is, children who start to develop low perceptions of their athletic abilities start to drop out. There are six important needs of young athletes that should be addressed by the structure in sports situations, by providing settings that

1. improve new skills,
2. encourage kids to have fun,
3. provide opportunities for developing friendships and positive peer experiences,
4. provide excitement and novelty in training,
5. teach young athletes how to monitor their own fitness, and
6. allow children to compete and develop goals that define winning not just as beating others but as achieving one's own standard.

Gould and Petlichkoff, demonstrating why children participate in and withdraw from sports, have published a motivational model of youth sports participation. According to their model, the chief reason for children to prematurely withdraw from sports is perceived competence, goal orientations, and stress response.

Character Development

There is a long-standing relationship between good sportsmanship and character development. Youth sports is a ripe forum for cultivating good sportsmanship behaviors on the part of coaches, parents, and athletes, leading to longer-term character development. Weinberg and Gould define character as an array of characteristics (usually referring to a positive moral overtone) that can be developed in sports. They describe athletes of good character as being able to overcome obstacles, cooperate with teammates, develop self-control, and persist in the face of defeat. They connote that character in sports consists of four interrelated virtues: (1) compassion, (2) fairness, (3) sportsmanship, and (4) integrity. Compassion is a form of empathy that is the ability to take on and appreciate the feelings of others. Integrity is the ability to maintain one's morality and fairness, along with the belief that the athlete can remain moral in his or her actions.

The Johnston Alliance for Character Development notes five common core principles associated with fostering good sportsmanship and character development:

1. *Trustworthiness:* Pursue victory with honor and fair play.
2. *Respect:* Engage within the boundaries of the guidelines of the sport. Win and lose with dignity.
3. *Responsibility:* Be a responsible role model on and off the field.
4. *Fairness:* Adhere to standards of fair play.
5. *Caring:* Understand that emotional, physical, and moral well-being are always placed above desires and pressures to win.

Talent Development of the Young Athlete

There are a number of ways to look at the development of young athletes. Jon H. Hellstedt looks at the parallel processes of the development of young athletes and the correlated changes in the family system supporting the training of young athletes. He has identified three main stages of development that must be completed for a child athlete to become successful in his or her sport.

Phase 1: Exploration

The first phase is exploration; this phase usually occurs between the ages of 4 and 12. Shane Murphy termed this Phase 1 and noted that it nicely emphasizes the sense of trying different sports and the excitement of exploring one's skills. Hellstedt describes that parents negotiate several objects within each phase for the child athlete to develop successfully. In this first phase, parents and coaches need to emphasize fun and skill development while minimizing competitive success.

Phase 2: Commitment

As skill, success, and fulfillment emerge through a sport, the young athlete makes an increasing commitment to the chosen sport. This phase is marked by the athlete taking responsibility for the skill development process. This is often a time when a talented athlete starts to make choices between sports and other activities to make a primary commitment to skill development in one sport. Murphy describes a potential deterrent during this phase, what he calls the "externalization" of sports. It is during this phase that the outcomes of games and performance or working to make a team or not being cut from a team start to shape the young athlete's experience. When sports experience is more heavily weighed as externally driven, the athlete may lose his or her passion for the sport or may experience burnout. Programs, coaches, and parents need to remain mindful through all phases of sports development that the critical elements that brought the young athlete to the sport remain a vital component of his or her experience.

Phase 3: Proficiency

This phase of athletic training maximizes the commitment phase and takes training to a new level. This phase is marked by long hours of training, expert coaching, and participation in very competitive situations and events. As referenced earlier, the phases of proficiency vary by sport. In gymnastics and figure skating, for example, proficiency needs to be accomplished by the midteen years, and executing training with this level of commitment starts at a very young age. The development impact on younger athletes is different from the proficiency that may be required of a soccer player who is expecting to start peaking in his or her late teens and college years. Most Division I college athletes are living the life of a proficient athlete, being required to make the compromises necessary to maintain a high-level commitment to sports while remaining strong in academics. The conflict between pleasure and external demands has an impact on the athlete's experience of the sport.

Young Athletes and Competition

As youth sports promote competition and specialization in a sport at younger and younger ages, the developmental appropriateness of these experiences for developing athletes becomes a matter of concern. Important questions are raised about the enhancing aspects of competition as well as how competitiveness at an early age can lead to loss of interest in the sport and premature termination of sports participation. The themes that emerge surrounding the value of competition include building teamwork and leadership skills as well as personal discipline and following through on commitments. Others are concerned that premature exposure to competition can lead to injuries to self-esteem and premature termination of sports participation.

Sport psychology research on this issue has demonstrated that it is the attitude of the athlete that determines the strength or weakness associated with the experience of competition. It has also been demonstrated that by adolescence, athletes have formed a stable set of attitudes regarding competition—termed *competitive orientation.* There are two dimensions that characterize competitive orientation. The ego orientation is characterized by the athlete's concern to "look good." This orientation is marked by social comparison, and athletes value their own expertise based on how it compares with the skills or competence of their peers. The mastery orientation toward competition values excellence in one's sport. This dimension of the athlete's experience values skill acquisition and becoming an expert in the chosen sport.

Murphy holds that the strength of an athlete's orientation between the ego and mastery orientation will have significant implications. The four styles are (1) high ego, high mastery; (2) high ego, low mastery; (3) low ego, high mastery; and (4) low ego, low mastery. An athlete with high ego, high mastery is often considered "competitive." This athlete enjoys competition as an environment to test out his or her own skills and works hard to reach higher levels in his or her sport. This athlete measures progress according to his or her own standards and pushes to improve skill level based on external and internal comparisons. In contrast, the low ego, low mastery style has low levels of both types of goal orientations. This athlete is not driven by internal standards but instead is participating in sports to please parents, be with friends, or please some other external motivator. This athlete does not value skill acquisition and is unlikely to remain in competitive sports for very long because the demands of training will prove to be taxing or frustrating.

This concept of competitive orientation sheds light on how parents and coaches can encourage the "right fit" for levels of competition for the young athletes participating in youth sports.

Sharon A. Chirban

See also Anger and Violence in Sports; Arousal and Athletic Performance; Attention Focus in Sports; Biofeedback; Exercise Addiction/Overactivity Disorders; Hypnosis and Sport Performance; Imagery and Visualization; Mental Health Benefits of Sports and Exercise; Personality and Exercise; Psychological Aspects of Injury and Rehabilitation; Young Athlete

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Pulmonary and Cardiac Infections in Athletes

Pulmonary and cardiac infections in the athlete can have a wide range of presentations and complications.

Such infections may present few problems for the training athlete, but they also have the potential to become a life-threatening condition. The team physician must be able to recognize the diagnosis, give the appropriate treatment, understand the potential complications, and ensure proper follow-up and return-to-play protocols.

Pneumonia

Pneumonia is defined as an acute infection or inflammation of the pulmonary parenchyma. The term *community-acquired pneumonia* (CAP) is used when a patient is not hospitalized or in a long-term facility for at least 14 days prior to the onset of symptoms. Typical pneumonias are most commonly caused by *Streptococcus pneumoniae* and are found in patients very young or older. Atypical pneumonias are usually caused by legionella, chlamydia, or influenza organisms; are found most often in young adults; and account for 20% to 40% of cases of CAP. CAP generally is a more serious illness with considerable morbidity and mortality and requires increased recovery time for the athlete.

Clinical Presentation

Cough is the most common symptom in CAP. Symptoms may also include sputum production, shortness of breath, and chest pain. Patients may present with nonspecific symptoms such as malaise, anorexia, headache, myalgias, fever, and chills.

It is imperative to document the vital signs (temperature, pulse, respiratory rate, blood pressure, and oxygen saturation) of any athlete who presents with a respiratory complaint. The vital signs on physical exam may reveal fever, tachycardia, tachypnea, hypoxemia, or hypotension. The most common sign associated with CAP is fever. Vital signs are important elements in the decision-making process on the appropriate management of CAP.

The examination may demonstrate crackles, rales, or bronchial breath sounds on auscultation. It is also important to document the patient's appearance and neurological status.

Diagnosis

An infiltrate on chest radiograph is considered the "gold standard" for the diagnosis of pneumonia in the appropriate clinical scenario.

Treatment

Once the diagnosis of CAP has been made, physicians must choose between inpatient treatment and outpatient treatment for the athlete. In the training room setting, the most useful indicators are vital signs and physical exam findings.

The most common contraindications to outpatient treatment are inability to maintain oral intake, unstable vital signs, history of substance abuse, mental/cognitive impairment, or the presence of comorbid conditions.

Antibiotics that provide coverage against the most common organisms known to cause CAP (*S. pneumoniae, Mycoplasma pneumoniae, Chlamydia pneumonia, Legionella*) should be selected.

Generally, most cases of CAP should be treated for 7 to 10 days. The severity of the clinical presentation and the presence of coexisting illnesses should be considered in the decision on duration of antibiotic treatment.

Complications

Most patients recover from CAP without complications. One of the most common complications for the athlete is reactive airway disease. This abnormality typically resolves after 3 weeks but may last up to 2 months. This potential complication could inhibit the athlete's ability to fully return to play. If clinically indicated, the athlete may respond to short-term inhaled bronchodilator therapy.

Return to Sports

Athletes treated with an effective drug regimen usually show improvement of symptoms within 72 hours. The athlete should be afebrile prior to returning to training and competition. The athlete also should be reevaluated by the team physician prior to clearance to ensure normalcy of the vital signs and respiratory status. Once the athlete is able, we recommend restarting exercise and training slowly.

Acute Bronchitis

Bronchitis is defined as inflammation of the bronchial mucous membranes. Acute bronchitis is a clinical syndrome characterized by cough (with or without sputum production) lasting up to 3 weeks, with evidence of concurrent upper airway infection.

Causes

Respiratory viral infections are the most common causes of acute bronchitis. The most common viruses associated with acute bronchitis include influenzas A and B, adenovirus, rhinovirus, parainfluenza, coronavirus, and respiratory synctial virus (RSV). When contemplating treatment options, it is important for the physician to understand the limited role of bacterial agents in acute bronchitis. Acute bronchitis is one of the most common examples of the misuse of antibiotics by the primary care physician.

Clinical Evaluation

Cough is the most common symptom in acute bronchitis. The patient may or may not have sputum production. Fever is unusual in acute bronchitis. The patient may also complain of concurrent or prodromal symptoms of an upper respiratory infection (URI), including pharyngitis, coryza, and fatigue. Most URI symptoms improve within 5 to 7 days. In acute bronchitis, the cough can last up to 3 weeks.

It is imperative to document vital signs (temperature, pulse, respiratory rate, blood pressure, and oxygen saturation) on any athlete who presents with a respiratory complaint. The exam will often reveal similar findings as in URIs—pharyngeal erythema, anterior cervical lymphadenopathy, and rhinorrhea.

Diagnosis

The diagnosis of acute bronchitis is considered a clinical diagnosis and should be suspected in cases of acute respiratory disease with prolonged cough that continues after other signs and symptoms of acute infection have resolved. It is likely not necessary to obtain any further studies in the appropriate clinical situation.

Treatment

Once the clinical diagnosis of acute bronchitis has been established, the recommended therapy is symptomatic. The physician may choose to use acetaminophen, ibuprofen, and nasal decongestants if appropriate.

Return to Sports

There are few data regarding appropriate return-to-play issues for athletes with acute bronchitis. It is important for proper follow-up with the team physician to ensure resolution of symptoms and to guarantee a nonworsening clinical situation.

Pertussis

Bordetella pertussis, a gram-negative coccobacillus, is a commonly undiagnosed cause of acute bronchitis. *Pertussis*, also known as "whooping cough," is an acute, highly contagious infection of the respiratory airways. Pertussis is transmitted from person to person by contact with aerosolized droplets. Due to the amount of time that athletes spend training together and the high infectivity of pertussis, this is a diagnosis that must not be missed in the training room.

Clinical Presentation

The classic clinical course of pertussis is divided into three stages: (1) catarrhal phase, (2) paroxysmal phase, and (3) convalescent phase. Table 1 describes each stage of pertussis. Athletes may report a cough lasting more than 2 weeks with a paroxysmal quality, posttussive emesis, or inspiratory whooping cough.

Diagnosis

The most reliable diagnostic test for pertussis is detection of the organism from nasopharynx secretions. The Centers for Disease Control and Prevention (CDC) recommends that physicians report and treat pertussis once there is clinical suspicion and not wait for laboratory confirmation.

Treatment

In the case of proven or presumed infection, therapy should be started as soon as pertussis is suspected. The recommended treatment is erythromycin for 14 days. Athletes with confirmed or

Table 1 Stages of Pertussis

Catarrhal Phase	*Paroxysmal Phase*	*Convalescent Phase*
Lasts 1 to 2 weeks	Lasts 3 to 6 weeks	May last 2 to 12 weeks
Most contagious phase	Clinically, spells of coughing with characteristic inspiratory whooping	Cough still present
Clinically resembles upper respiratory tract infection	Posttussive vomiting, cyanosis, and apnea	Paroxysms may recur with respiratory infection
Cough increases in severity and frequency		

probable pertussis should be isolated for 5 days from the start of treatment.

Prophylaxis

Athletes known to be in close contact with a known or suspected case of pertussis should be given prophylactic antibiotic treatment. The recommended regimen is full dosing of erythromycin for 14 days.

Complications

Pertussis infections in the training room can lead to rapidly spreading illness among other athletes and staff. Pertussis can also cause reactive airway disease and bronchitis. Pertussis can be complicated by pneumonia, dehydration, weight loss, and sleep disturbance—all of which can affect the athlete's return-to-play status as well as overall performance.

Return to Sports

Athletes with confirmed or probable pertussis should be isolated for 5 days from the start of treatment to prevent spreading of the disease. The athlete should also be evaluated to ensure resolution of respiratory symptoms.

Influenza

Influenza is an acute respiratory illness caused by influenza A or B viruses. Influenza is a common seasonal cause of acute bronchitis.

Clinical Presentation

The diagnosis of influenza should be considered if the athlete presents during the winter months with the abrupt onset of fever, headache, myalgias, malaise, nausea, and vomiting. These symptoms are generally accompanied by cough and sore throat.

In uncomplicated influenza, there are few physical exam findings. The health care provider in the training room should document the vital signs. The patient may appear flushed. The findings may also include mild cervical lymphadenopathy and hyperemic oropharynx. The eyes may be watery or reddened. Otherwise, the exam will likely be unremarkable.

Diagnosis

Outpatient laboratory diagnosis of influenza can be accomplished by the detection of the virus or viral antigen in nasal washes or throat swabs.

Treatment

There are two classes of antiviral drugs available for the treatment of influenza: With appropriate treatment, the duration of the symptoms may be reduced by 2 to 3 days.

Symptomatic treatment is also important in influenza. Acetaminophen or ibuprofen may be beneficial for fever, headache, or myalgias. Cough suppressants may be helpful in the appropriate clinical scenario. Athletes should be instructed to maintain proper hydration and rest during the acute illness.

Complications

Close follow-up of athletes with severe influenza illness is imperative to ensure that no complications are arising. Dehydration and acute bronchitis are common complications of influenza.

Prevention

There are measures available to help prevent the illness caused by influenza. Annual vaccination is available.

Return to Sports

To prevent the spread of influenza, the athlete should be kept away from the training room, practices, and competitions until 5 days after the onset of symptoms. Return to full activity should be delayed until the illness has fully resolved. Athletes should be evaluated for any signs of fever, dehydration, or impaired respiratory status prior to full clearance.

Myocarditis

Myocarditis is an inflammatory disease of the cardiac muscle that can have a wide spectrum of clinical presentation and outcomes. Myocarditis is one of the most challenging diagnoses in cardiology. Acute myocarditis can progress to dilated cardiomyopathy, heart failure, arrhythmias, and death. If unrecognized in the training room, myocarditis can produce lethal results.

Causes

Myocarditis has a wide variety of etiologies, both infectious and noninfectious. The most common infectious causes are viruses. The most frequently associated are coxsackie B virus, adenovirus, hepatitis C, cytomegalovirus, echovirus, influenza, and Epstein-Barr virus. The most common etiologies of myocarditis found in the training room are viral illnesses—especially coxsackie B virus, adenovirus, and echovirus. Myocarditis can also result from drug hypersensitivity, radiation, and chemical or physical agents.

Clinical Presentation

The diagnosis of myocarditis requires a high index of suspicion in the appropriate clinical setting. A wide range of symptoms can be present in an athlete suffering from myocarditis. The patient may be asymptomatic or may simply give a history of a preceding upper respiratory infection or flu-like syndrome. The patient may also present with chest pain or symptoms of heart failure. The athlete may present with fever, malaise, and arthralgias. The diagnosis of infective myocarditis should be considered when an athlete presents with cardiac complaints or arrhythmia issues in the course of a recognized systemic infection.

It is imperative to document vital signs in the training room. The physical exam may be normal. If the myocarditis is severe, the cardiac exam may reveal tachycardia, a muffled first heart sound along with a third heart sound, and a murmur of mitral regurgitation. The exam may also reveal findings of heart failure such as edema and pulmonary crackles from fluid overload, depending on the severity of the illness. If there is associated pericarditis, a pericardial friction rub may be heard. The exam may also reveal findings consistent with an upper respiratory infection.

Diagnosis

Routine blood and urine laboratory tests are generally normal in myocarditis. Cardiac enzymes may be elevated, specifically the MB (muscle and brain) fraction of creatine kinase (CK-MB) and troponin I. The electrocardiogram (EKG) may be normal or abnormal. The most common EKG findings are transient, nonspecific ST-T wave abnormalities. Chest radiograph findings range from normal to cardiomegaly. Echocardiogram may reveal decreased ventricular function.

Cardiac magnetic resonance imaging (MRI) is becoming a more widely available tool to detect myocardial abnormalities. The definitive diagnosis of myocarditis is made by endomyocardial biopsy with histologic evaluation.

Treatment

Viral myocarditis is usually a self-limited disease. Treatment is generally supportive. However, myocarditis may progress to dilated cardiomyopathy and heart failure. Most therapy regimens are directed toward treatment of heart failure and potential arrhythmias in serious cases.

Complications

Most patients with viral myocarditis recover completely. However, athletes with viral myocarditis are at risk for heart failure, cardiomyopathy, and associated pericarditis. These athletes are also at risk for arrhythmias and sudden cardiac death.

Return to Sports

Exercise and training can be deleterious in athletes with myocarditis. According to the current Bethesda Conference recommendations, athletes with probable or definitive evidence of myocarditis should be withdrawn from all competitive sports and should undergo a convalescent period of about 6 months following onset of clinical manifestations. After 6 months, athletes may return to training if the following conditions are met:

- Left ventricle function, wall motion, and cardiac dimensions return to normal.
- Clinically relevant arrhythmias are absent on ambulatory Holter monitoring and graded exercise testing.
- Serum markers of inflammation and heart failure have normalized.
- The EKG has normalized.

Pericarditis

Pericarditis (inflammation of the pericardium) may be caused by a wide variety of infectious and noninfectious processes. Pericarditis can have a wide range of clinical presentations from asymptomatic to severe hemodynamic compromise. A careful history and knowledge of the clinical presentation of pericarditis are important in establishing the diagnosis. If the diagnosis is missed, pericarditis can become life threatening for the athlete.

Causes

Pericardial disease has multiple etiologies, including infectious, neoplastic, inflammatory, degenerative, vascular, and idiopathic. Infectious and idiopathic causes will likely be the most common etiologies in the training room. These causes are found in 90% of cases of acute pericarditis.

Clinical Presentation

The presentation of acute pericarditis varies depending on the etiology. In infectious or idiopathic acute pericarditis, the major clinical symptom is chest pain. The patient may describe the pain as retrosternal, exacerbated by coughing or deep inspiratory effort. The pain may also radiate to the back. The chest pain in acute pericarditis is often positional—worsened in the supine position and relieved by sitting upright and leaning forward. The athlete may also complain of fever. Patients may also present with an associated flulike illness with cough, fatigue, myalgias, or arthralgias.

It is imperative to document vital signs for athletes with cardiac or respiratory complaints. The vital signs may indicate severity of cardiac compromise. The pericardial friction rub is the cardinal physical sign of acute pericarditis. The physician should also look for signs of cardiac tamponade on exam: hypotension, tachycardia, jugular venous distention, and pulsus paradoxus (defined as an inspiratory systolic decrease in arterial pressure of 10 millimeters of mercury pressure [mmHg] during normal breathing).

Diagnosis

Laboratory tests to consider include complete blood count (CBC), erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and cardiac enzymes. The EKG is abnormal in 90% of patients with acute pericarditis. In acute pericarditis, the chest radiograph is generally normal. An echocardiogram should also be obtained in patients with suspected acute pericarditis. The echocardiogram is often normal unless there is an associated pericardial effusion.

Treatment

The initial treatment decision the physician must make is inpatient or outpatient treatment. If the athlete has simple uncomplicated acute pericarditis and is clinically stable, outpatient treatment with close follow-up may be appropriate. If high-risk features are present or if the patient is clinically unstable, inpatient treatment is recommended. High-risk features are illustrated in Table 2.

Table 2 High-Risk Features in Acute Pericarditis

Subacute onset
Fever (temperature >100.4 °F)
Leukocytosis
Acute trauma
Evidence of cardiac tamponade
Immunosuppressed state
Large pericardial effusion without significant response to NSAID treatment
History of oral anticoagulant therapy
Failure to respond to NSAID therapy within 7 days

Primary therapy goals for idiopathic or viral pericarditis are pain relief, resolution of inflammation, and resolution of effusion if present. Current recommendations include the use of aspirin and other nonsteroidal anti-inflammatory drugs (NSAIDs). Close monitoring and follow-up are imperative for all athletes diagnosed with acute pericarditis.

Complications

While pericarditis usually resolves within a few days to weeks, life-threatening complications can occur. If an associated pericardial effusion is present, this may proceed to a cardiac tamponade—which is a cardiac emergency. If the pericardial inflammation does not resolve, it may lead to chronic pericarditis. Chronic pericarditis may subsequently lead to constrictive pericarditis.

Return to Sports

The current Bethesda Conference Guidelines recommend exclusion of the athlete with acute pericarditis from competitive sports. These athletes can only return to full activity when there is no evidence of active disease.

Acute Rheumatic Fever

Acute rheumatic fever (ARF) is an inflammatory disease that may develop after an infection with streptococcus bacteria and can involve the heart, joints, skin, and brain. The cardiac manifestations associated with acute rheumatic fever, valvulitis, or carditis can be a potentially serious infection found in the training room.

Cause

ARF results from infection with a "rheumatogenic" strain of Group A streptococcus. Studies have shown that an estimated 3% of individuals with untreated Group A streptococcal pharyngitis will develop rheumatic fever.

Clinical Presentation

The clinical presentation is variable. The Jones Criteria shown in Table 3 are established guidelines to aid in the diagnosis. The onset of rheumatic fever follows a latent period of 7 to 35 days after a preceding Group A streptococcal infection.

On exam, the carditis is usually associated with a murmur of valvulitis. The exam may reveal sinus tachycardia, an S3 gallop, a pericardial friction rub, and/or cardiomegaly. The valvulitis may be characterized by a pansystolic murmur of mitral regurgitation (MR), best heard at the apex, with radiation to the left axilla.

Diagnosis

The diagnosis of ARF is a clinical one but requires supporting evidence from clinical presentation as well as microbiological and immunological labs. To fulfill the Jones Criteria, either two major criteria or one major and two minor criteria *plus*

Table 3 Jones Criteria for Rheumatic Fever

Major	*Minor*
Carditis	Fever
Polyarthritis	Arthralgia
Chorea	Previous rheumatic fever or rheumatic heart disease
Erythema marginatum	
Subcutaneous nodules	

evidence of an antecedent streptococcal infection are required. An EKG and echocardiogram are important diagnostic tools to assess for cardiac involvement.

Treatment

Hospital admission is recommended for all cases to ensure complete and proper investigation. The main treatment goals are to confirm the diagnosis, treat cardiac failure, reduce the duration of symptoms, and ensure ongoing secondary prophylaxis and clinical follow-up. The mainstay of treatment for ARF is NSAIDs, most commonly aspirin. Antibiotic treatment with penicillin should also be given for 10 days. The athlete will also need long-term antibiotic prophylaxis after the acute episode has resolved.

Complications

ARF can cause permanent cardiac damage. The mitral valve is more commonly involved than the aortic valve. Mitral stenosis (MS) is the classic finding in rheumatic heart disease and may require surgical correction. Other potential complications of ARF include heart failure, myocarditis, pericarditis, arrhythmias, and endocarditis. The athlete must have close monitoring and follow-up prior to any return to exercise.

Return to Sports

If the athlete has no cardiac involvement with ARF, once antibiotic treatment is complete and the athlete is afebrile, gradual return to play may be initiated with close physician observation. This is normally about 3 to 4 weeks into treatment. The athlete should also have resolution of polyarthralgias and chorea if present prior to return to play. Prolonged bed rest is no longer recommended after ARF. All athletes with cardiac involvement should be followed by a primary care physician, cardiologist, and dentist.

Endocarditis

Infective endocarditis (IE) is a serious febrile infection that rapidly damages cardiac structures, spreads to extracardiac sites, and, if untreated, can progress to death within weeks. To avoid overlooking the diagnosis of IE, a high index of suspicion must be maintained.

Causes

A variety of microbial agents can cause IE. Staphylococci, streptococci, and enterococci represent the majority of cases. The most common risk factor in athletes is structural heart disease.

Clinical Presentation

Fever is the most common symptom. Other common symptoms include chills, night sweats, anorexia, dyspnea, cough, chest pain, and myalgias. The most common findings on physical exam are fever and a heart murmur. In an athlete with a preexisting murmur, a new or changing murmur may be noted. Other findings on exam may include splenomegaly or cardinal peripheral manifestations such as petechiae, splinter hemorrhages, osler nodes, janeway lesions, or roth spots.

Diagnosis

The diagnosis of IE should be investigated when athletes with fever also present with one or more of the cardinal manifestations of IE. The incorporation of clinical, laboratory, and echocardiographic data is central to the diagnosis.

Treatment

Treatment is usually started in the hospital with parental antibiotics but may be completed in the outpatient ward once the patient is afebrile and follow-up blood cultures are negative. Antibiotic therapy should be selected as appropriate based on blood culture and sensitivities results. Depending on the pathogen involved, antibiotic treatment should last between 2 and 6 weeks.

Complications

If left untreated, IE can progress to valvular damage, severe heart failure, and potentially fatal arrhythmias.

Return to Sports

From an infectious standpoint, prior to return to competition, the athlete should have completed at least 2 to 6 weeks of appropriate antibiotic treatment and should remain afebrile with negative follow-up blood cultures. The athlete will require close monitoring with frequent follow-ups. Once the antimicrobial treatment is complete, a repeat echocardiogram should be done to establish a new baseline. Repeat physical examinations are important to look for any signs of heart failure. Prior to any initiation of antibiotic therapy for any febrile illnesses, the athlete should have three sets of blood cultures obtained from separate sites. The athlete will also require thorough dental evaluations to ensure oral hygiene.

Cathy L. Cantor

See also Asthma, Exercise-Induced; Athlete's Heart Syndrome; Congenital Heart Disease; Physiological Effects of Exercise on Cardiopulmonary System

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Punch Drunk Syndrome

Punch drunk syndrome (PDS) is a neurological disorder that occasionally affects professional boxers and other professional athletes, such as wrestlers and American football players, who suffer repeated head trauma. It represents the late or chronic effects of repeated head trauma and is also frequently referred to as dementia pugilistica (DP), chronic traumatic encephalopathy (CTE), chronic boxer's encephalopathy, traumatic boxer's encephalopathy, and boxer's dementia, depending on the source cited. PDS develops over a period of years, with the average time of onset being about 12 to 16 years after the start of a career in boxing. The condition is believed to affect around 15% of professional boxers, but it can also affect other types of athletes. Famous sufferers include Jack Dempsey, Joe Louis, and Sugar Ray Robinson, among others.

The Pathophysiological Basis of PDS

PDS was first described by Harrison S. Martland in 1928 as being characteristic of boxers who had suffered frequent, repetitive head trauma of concussive or subconcussive force. In his landmark article "Punch Drunk," Martland described the early symptoms of PDS as a slowing and confusion of thought processes, nonfluent speech, slowed muscle movement, and hand tremors. Occasionally, these progressed to a more chronic state that manifested with marked truncal ataxia, gross mental deterioration, and a syndrome similar to Parkinsonism.

Over the next half-century, multiple retrospective studies were conducted that supported Martland's observations. In *Brain Damage in Boxers* (1969), Roberts reported on 224 British boxers and found a similar "dose response" in the nature of symptoms. In his study, 17% of the cases demonstrated chronic neurological deficit attributable to boxing, and the prevalence of injury increased with increasing boxing exposure.

Pathological evidence of this was offered by Corsellis et al. in 1973 in the article "The Aftermath of Boxing." They conducted postmortem studies on the brains of 15 boxers. Corsellis's team documented four types of changes in the brain tissue. The most common was rupture of the septum pellucidum (leading to cavum septum pellucidum), which they correlated with the emotional lability and rage reactions of the boxers. The second was scarring of the undersurface of the cerebellum, which was thought to occur due to the cerebellum being repeatedly forced through the foramen magnum. This cerebellar injury was associated with slurred speech, slowing of motor movements, and a broad-based gait. In some, there was progression of pathological changes, which was characterized by a decrease of pigment in the substantia nigra. This is also seen in Parkinson syndrome, and four of the boxers who had tremors and rigidity of the limbs were actually hospitalized with Parkinson syndrome. The fourth change was neurofibrillary tangles that represent tau protein deposition in nerve cells. These neurotoxic tau protein deposits were especially prevalent in the medial temporal lobes. This was seen in more than 90% of the boxers. Corsellis et al.'s study also demonstrated that the most successful boxers had the most brain damage. They reasoned that this was because the boxers had the longest careers, fought the most fights, and had consequently received the most head trauma.

Table 1 summarizes the findings of Corsellis et al., and although four different areas are presented, only 8 of the 15 cases had all four pathological features present. Corsellis also reported PDS findings in jockeys, professional wrestlers, parachutists, and even a case of battered wife syndrome. The table outlines the major clinical signs and symptoms seen with respect to areas of the central nervous system that are damaged in patients who develop PDS.

A less severe form of PDS that has only the neurofibrillary tangles and is clinically manifested by recent memory failure, depression, and erratic emotional behavior has been reported in retired National Football League football players (Mike Webster, Andre Waters, Terry Long, and Justin Strzelczyk) and Chris Benoit, the wrestler.

Other pathological hypotheses have also been considered. In 2001, Geddes et al. examined slices of brain from patients who had had multiple mild traumatic brain injuries and found changes in the cells' cytoskeletons, which they suggested might be due to damage to cerebral blood vessels. Furthermore, as it has not been conclusively shown that repeat concussions necessarily lead to cumulative brain damage, some scientists argue that boxers who get chronic traumatic encephalopathy are

Table 1 The Four Main Components of Chronic Brain Damage in Punch Drunk Syndrome

Area Damaged	*Clinical Symptoms and Signs*
Septum pellucidum, adjacent periventricular gray matter, frontal and temporal lobes	Altered affect (euphoria, emotionally lability) and memory
Degeneration of substantia nigra	Parkinson syndrome (bradykinesia, rigidity, gait instability, and tremor)
Cerebellar scarring and nerve loss	Slurred speech, loss of balance, and coordination
Diffuse neuronal loss	Loss of intellect, Alzheimer syndrome

Source: Adapted from Cantu RC. Chronic traumatic encephalopathy in the National Football League. *Neurosurgery*. 2007;61(2):223–225.

genetically predisposed to it. For example, it has been suggested that boxers with the apolipoprotein Eε-4 gene may be at higher risk for CTE.

Clinical Features of PDS

Two common chronic brain injuries that occur are postconcussion syndrome (PCS) and PDS.

PCS is the second late effect of a concussion. It consists of headache (especially with exertion), dizziness, fatigue, irritability, impaired memory, and concentration. While its true incidence is unknown, its persistence indicates an alteration in neurotransmitters and correlates with the duration of posttraumatic amnesia. These athletes should be evaluated with a computed tomography (CT) scan and neuropsychiatric testing while symptoms persist. Return to competition must be deferred until all diagnostic and clinical findings are normal; otherwise, the athlete is at risk for the controversial second-impact syndrome (SIS). SIS is a rare condition in which the brain swells rapidly and usually catastrophically after a person suffers a second injury before the symptoms from the first injury have subsided. Even the mildest grade of concussion can lead to SIS, and the condition is often fatal (~50%) if not severely debilitating (~100%). It is thought that SIS occurs due to the loss of autoregulation of the cerebral vasculature, and treatment is generally nonsurgical and supportive in nature.

PDS represents the chronic effects of repeated head trauma of concussive and subconcussive force that lead to anatomical patterns of brain injury with correlating clinical features. The characteristic features include emotional lability with mood swings and a diminished ability to control one's temper (which can be violent). The prevalent mood is generally one of fatuous cheerfulness, but depression and paranoia may also occur. Often, cognitive function deteriorates, and dementia may ensue. Other signs and symptoms due to substantia nigra injury include Parkinsonism-like features (bradykinesia, rigidity, gait instability, and tremors), while cerebellar injury leads to slurred speech, loss of balance, and incoordination.

While the studies of Martland, Roberts, and Corsellis demonstrated the pathophysiological basis of PDS and correlated it to the clinical features, current technology such as the CT scanner and magnetic resonance imaging (MRI) can assist with the diagnostic aspects of PDS. In one report using the CT scan, it was demonstrated from the data that even boxers with a moderate number of bouts may suffer cerebral atrophy. Furthermore, the authors found that the degree of atrophy correlated to the number of bouts the athlete had participated in. Other articles have since confirmed or indicated similar findings.

Conclusion

The previously cited studies do document cerebral injuries and attempt to correlate them to the athlete's sport and mechanism of injury, but a cautious interpretation of the data is warranted as they were all retrospective and cross-sectional in design. Additionally, it is not absolutely certain that all pathological and clinical changes followed chronic head trauma, as there could be other confounding factors in the athlete's personal and social lifestyles. Furthermore, although these studies were limited by the absence of a control group, the athletes in question belong to a selective group in themselves, and therefore, drawing any conclusions while comparing them with the population at large would be inappropriate and inconclusive.

Nevertheless, as current and future technology is incorporated into the diagnosis and management of PDS and other similar conditions such as traumatic encephalopathy, relevant and important data should present themselves that would help make identifying and supporting the athletes at risk easier and perfunctory. Indeed, the time has arrived for prospective studies to be carried out to ascertain the true incidence of PDS and other related conditions, but this should only be considered in concert with the formation of independent, qualified committees so as to eliminate any bias that could occur.

Mayur Jayarao, Lawrence S. Chin, and Robert C. Cantu

See also Boxing, Injuries in; Concussion; Head Injuries

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Puncture Wounds

Millions of Americans across the country are involved in athletics and recreational activities on a daily basis. Inherent to many of these endeavors is the risk of trauma to the dermatologic system. The most frequent types of mechanical skin injuries are abrasions, lacerations, and puncture wounds. The majority of skin trauma (approximately 50%) involves the head and neck, with the second most common site of injury being the upper extremities (approximately 35%). This entry discusses puncture wounds and will review the common histological and anatomic structures relevant to the skin, the approach to evaluation of a puncture wound, the management of these wounds, and the complications of these injuries.

Puncture wounds are defined as a wound to the skin in which the opening is relatively small as compared with the depth. These wounds are most often caused by a narrow pointed object, such as a shard of wood, glass, or metal. There are myriad sporting activities that may cause puncture injuries to the skin. Some of the common puncture wound injuries in sports are caused by metal cleats, fishhooks, and accidental tooth penetration. There are also case reports of hockey sticks breaking and causing wooden or composite puncture wounds with retained foreign bodies. Other, more rare but potentially devastating puncture wounds seen in hockey are deeply penetrating wounds from skates involving the axillary or carotid arteries. Surfing and open-water swimming carry the risk of puncture wounds caused by stings from aquatic creatures such as needlefish or stingrays. Fencing injuries can also be quite dangerous and have included puncture wounds through the chest wall, causing a collapsed lung, and wounds to the neck, causing laryngeal injury. Many of these activities have protective equipment designed to minimize puncture injuries, but it is the participants who must ensure the proper use and maintenance of equipment to fully protect themselves from puncture wounds and their potential complications.

The first step to understanding and treating these wounds is to briefly review skin anatomy. Skin is composed of three histologically and functionally distinct layers. The outermost layer is the epidermis. This layer serves as the first line of defense against pathogenic organisms, maintains the separation between our fluid-filled bodies and the outside environment, and protects against destructive ultraviolet (UV) rays from the sun. This layer can vary in thickness from 0.075 millimeters (mm), for example, along the eyelid, to 0.6 mm, as in the soles of the feet. The next layer is the dermis, which contains a variety of structures, including sensory nerves, various oil and sweat glands, very small arteries and veins, and finally hair follicles. These structures are anchored in a dense connective tissue called collagen. Finally, there is the subcutaneous layer, which is composed mostly of fatty tissue, which serves to insulate and mechanically protect the underlying structures. When grossly viewing these layers, the epidermis is the thin fleshy outer layer, followed by the dermis, which is whitish and denser appearing. Last, the subcutaneous layer is yellow with globules of fat. These layers can usually be visualized when evaluating puncture wounds.

The majority of puncture wounds involve only the epidermal and dermal layers of the skin and heal well with simple wound care and hygiene. However, once an object has penetrated into the subcutaneous layer, the medical provider must increase his or her vigilance to look for more insidious injuries to the underlying structures, as well as unseen retained foreign bodies. Beneath these layers of skin, there are many vital structures and organs that can easily be damaged by puncture wounds. Due to the nature of the puncture wound, a serious underlying injury can easily go unnoticed if full clinical evaluation is not performed.

The location on the body, mechanism, environment, and material of the penetrating object are the key components to understanding how to manage puncture wounds. When considering the location of the puncture wound, injuries requiring immediate attention by a physician include injuries to the larger blood vessels, in which it can be difficult to stop bleeding; injuries causing neurologic compromise; and injuries into a tendon/tendon sheath or joint space. Other site-specific areas requiring prompt physician evaluation include the eye/eyelid, face, neck, chest, abdomen, and genitals. In these cases, vital organs may be damaged, and identification of injury may not be evident until many hours later. If injuries to these areas are clearly complicated, transport to the emergency department and appropriate specialist involvement are warranted.

When evaluating a puncture wound, it is first necessary to obtain a very good history, including the following:

- Type of penetrating object, including its breakability
- Force of the object when it entered the skin
- Location of the wound on the body
- Environment in which the puncture took place (i.e., water or land)
- Time elapsed since the injury
- Relevant medical history of the patient, including the last tetanus vaccination

The next steps are to inspect and treat the wound in the following order:

- If you are on the scene of the incident, *ensure that the area is safe* for yourself and the patient.
- *Use universal precautions* to protect yourself and your patient from unintended exposures to blood-borne diseases.
- *Inspect* the wound.
- If necessary, *stop the bleeding* with direct pressure on the wound.
- If you have the supplies, gently *irrigate* with sterile saline, and remove any visible foreign bodies. (*Note:* It is not recommended to probe for deeper foreign bodies as you may cause more damage to the underlying structures and increase the risk of infection.)
- Attempt to *visualize the depth* of the wound.
- *Clean the wound* by gently scrubbing or rinsing the wound with an agent such as chlorhexidine gluconate. (*Note:* It is no longer recommended to use hydrogen peroxide as it may destroy healthy tissue as well as pathogens.)
- *Do not suture* puncture wounds, to avoid sealing in a potential foreign body or infection.
- *Cover* with a sterile dressing and apply pressure with tape.
- Arrange for *tetanus vaccination* based on the current Centers for Disease Control and Prevention (CDC) guidelines (see Table 1).

The most common complications of puncture wounds are infection and retained foreign bodies. These are often interdependent issues as foreign bodies often harbor pathogenic organisms, which thereby seed infection into the surrounding tissue. If there is suspicion of the presence of foreign bodies, further evaluation with X-rays is indicated. This method will detect most radio-opaque objects. Other methods such as ultrasound, computed tomography, and, rarely, magnetic resonance imaging (MRI) are needed to further characterize foreign bodies or infections that are unseen by plain X-rays.

The choice of antibiotic coverage for infected wounds depends on the penetrating material and the environment. The majority of cases involve staphylococcus and streptococcus species located on the patient's own skin. If the penetrating object has soil, saliva (human or animal), or other fecal contaminants, a broad spectrum of antibiotics will be needed to cover the large variety of potential

Table I CDC Summary Guide to Tetanus Prophylaxis in Routine Wound Management

	Clean, Minor Wounds		*All Other Wounds*	
History of Tetanus Immunization (Doses)	*Td*[a]	*TIG*	*Td*[a]	*TIG*
Uncertain or <3 doses	Yes	No	Yes	Yes
3 or more doses	No[b]	No	No[c]	No

Source: Centers for Disease Control and Prevention (2010). http://wwwnc.cdc.gov/travel/yellowbook/2010/chapter-2/tetanus.aspx.

a. For children <7 years old, DTaP or DTP (DT, if pertussis vaccine is contraindicated) is preferred to tetanus toxoid alone. For children ≥7 years of age, Td is preferred to tetanus toxoid alone. For adolescents and adults up to age 64, tetanus toxoid as Tdap is preferred if the patient has not previously been vaccinated with Tdap.

b. Yes, if >10 years since the last dose.

c. Yes, if >5 years since the last dose. More frequent boosters are not needed and can accentuate the side effects.

pathogens. Puncture wounds occurring in the water also necessitate broadening of antibiotic coverage.

Other complicating factors include patients who have medical comorbidities that limit the body's ability to fight infection or appropriately heal tissue damage. The most common and most concerning comorbidity is diabetes, especially if the wound involves the foot. These patients more often develop infection in the bone, and some studies estimate a fivefold increase in the need for multiple surgeries or amputation to clear an infection from a puncture wound. Other compromising factors include HIV (human immunodeficiency virus) infection, peripheral vascular disease, and cancer, as well as smoking.

Fortunately, the majority of puncture wounds are uncomplicated and rarely limit further participation in the activity in which they occurred. Knowledge of the underlying anatomic structures and suspicion of foreign bodies are essential for further management of puncture wounds. Furthermore, proper use of sporting equipment and understanding the environment in which you play can help avoid most puncture wounds altogether.

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See also Dermatology in Sports; Emergency Medicine and Sports; Fieldside Assessment and Triage

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Q

Q Angle

The *Q angle,* or quadriceps angle, is often measured when a physician is examining and evaluating a patient for knee pain. This angle is an important indicator of the biomechanical forces that act on the knee.

Measurement

The Q angle is formed between two lines representing pulling forces on the knee. The first line is the longitudinal axis of the femur (thigh bone), which represents the line of pull of the quadriceps muscles on the knee. This line is created by measuring from the center of the patella (kneecap) to the anterior-superior iliac spine of the pelvis. The second line represents the pull of the patellar tendon on the kneecap. Measuring from the center of the patella to the tibial tubercle creates this line (see Figure 1). The normal Q angle values are 17° in females and 14° in males. Women naturally have a larger Q angle than men because women tend to have wider pelvises than men. Other causes for increased Q angle include knock-knees (genu valgum), femoral anteversion, and other slightly abnormal alignment of the legs.

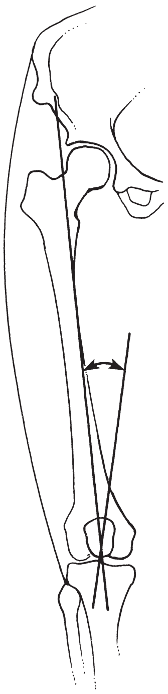

Figure 1 The Q Angle

Note: The Q angle is an important indicator of the biomechanical forces acting on the knee.

Problems Associated With a Large Q Angle

A larger-than-normal Q angle is associated with a disorder called abnormal quadriceps pull. In a patient with a large Q angle, the kneecap will be pulled sideways when the quadriceps muscle contracts. This increases the biomechanical stress on the knee during strenuous or repetitive activities and thus increases the likelihood of knee pain and injury. The abnormal pull of the quadriceps on the patella can also cause abnormal tracking of the patella in the femoral groove (the normal "track" in which the patella moves). The pain associated with this abnormal tracking is called patellofemoral pain syndrome. An increased Q angle also places a patient at increased risk for chondromalacia of the knee, patellar subluxation, and anterior cruciate ligament injuries.

Treatment

The goal of treatment is to decrease an abnormally large Q angle. One of the most effective ways to achieve this goal is to use custom-made, flexible orthotics. These shoe inserts are designed to help reduce stress on the knee.

Katherine Stabenow Dahab

See also Anterior Cruciate Ligament Tear; Chondromalacia Patella

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Quadriceps Strain

The quadriceps femoris muscle is located in the front of the thigh and is made up of four muscles: (1) rectus femoris, (2) vastus medialis, (3) vastus lateralis, and (4) vastus intermedius. The rectus femoris is in the middle of the thigh and covers the other quadriceps muscles. The vastus muscles are all deep to the rectus femoris and lie next to each other. The vastus medialis is the most medial, the vastus lateralis is the most lateral, and the vastus intermedius is in between the lateralis and medialis.

The rectus femoris originates from the ilium and therefore crosses both the hip and knee joint, whereas the vastus muscles originate from the femur and cross only the knee joint. All four of these muscles attach to the patella via the quadriceps tendon.

The quadriceps muscles are used to extend the knee as well as decelerate knee flexion when the heel strikes the ground. Because the rectus femoris muscle crosses the hip joint as well as the knee joint, it also functions as a hip flexor. These muscles are active during running, jumping, and walking. These muscles are composed predominantly of Type II fibers, which make them well suited for forceful rapid activities; however, they tire more easily than muscles composed of mainly Type I fibers, which are better suited for sustained activities.

Quadriceps muscle strains are actually small tears in the muscle. Muscle strains usually occur when an eccentric contraction occurs. An eccentric contraction occurs when the force generated by the muscle cannot overcome the resistance placed on the muscle. This causes the muscle fibers to lengthen as they contract (Figure 1). This type of contraction is used as a method of decelerating a body part or an object.

The musculotendinous junction is the location within the muscle where the strain most often occurs. Muscles that cross two joints in the body, such as the rectus femoris, are more susceptible to strain.

Quadriceps strains most often occur in individuals who are older and skeletally mature—that is, their *physes,* or growth plates, have closed. Younger, skeletally immature patients tend not to have quadriceps strains; oftentimes if a muscular strain is sustained, it is a low-grade strain. Instead of muscle strains, younger athletes are more susceptible to avulsion fractures. An avulsion fracture of the anterior-superior iliac spine can be caused by a forceful contraction of the quadriceps muscle in a child or adolescent who still has an open apophysis.

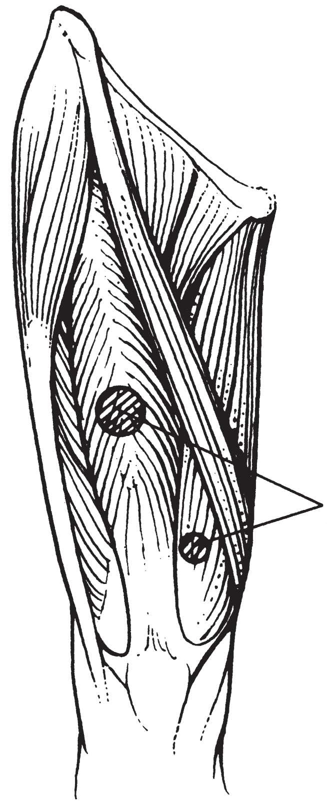

Figure 1 Quadriceps Muscles Strain

Notes: A quadriceps strain is among the most common injuries in sports. The quadriceps muscle most commonly injured is the rectus femoris, because, unlike the other three quadriceps muscles, it crosses two joints, the hip and the knee.

Histology

Muscle strains are tears that occur at a short distance from the musculotendinous junction. In the acute phase, there is disruption and hemorrhage in the substance of the muscle. By the second day, an inflammatory response may occur, and there may be edema within the muscle. One week after injury, fibrous tissue may be present, and this scar tissue remains within the muscle permanently.

Presentation

History

Athletes who participate in activities that involve a lot of sprinting are most susceptible to quadriceps strain. This includes, but is not limited to, hurdles, long jump, football, soccer, and basketball. Athletes who have a quadriceps muscle strain will sometimes state that they felt a popping or snapping in their thigh, immediately followed by a sharp pain. The pain has an abrupt onset.

Physical Exam

Often the athletes cannot walk properly and feel tightness in the affected thigh. It may be difficult for them to straighten their knee against resistance because it causes pain. Bruising may very well be noted over the area of injury. There is localized tenderness at the myotendinous junction. Varying degrees of swelling can occur depending on the severity of the strain.

Classification System

Quadriceps strains vary in severity. The severity of a muscle strain is classified according to its grade, with Grade 1 injury being the least severe and Grade 3 injuries being the most severe. First-degree injuries occur when the muscle is stretched, but there is no macroscopic damage. These are the least severe type of strain. Athletes usually recover rapidly from these injuries, with no functional loss. A second-degree injury occurs when the tendon or muscle is partially torn. This usually causes more bruising and inflammation than a first-degree injury and takes longer to recover. A third-degree strain is the worst type of strain, and this happens when there is a complete tear of the muscle or tendon. These athletes cannot perform at all secondary to their injury for quite some time, and depending on the location of their injury, they may need surgical repair. A practical grading for quadriceps strains is to class Grade I strain with those in which painless knee flexion is greater than 90°; second-degree strains have a flexion of 90°, and third degree strains have flexion less than 90°.

Treatment

The treatment of quadriceps muscle strains varies depending on the severity of the injury. Once an athlete has suffered this injury, it is more likely to recur if the quadriceps has not healed completely. Therefore, the best treatment of quadriceps strain is to prevent it from occurring. This can be done with well-ordered and strictly controlled stretching and warm-up programs before each practice and competition.

After a muscle strain has occurred, the initial treatment is rest, ice, compression with elastic wraps, and nonsteroidal anti-inflammatory drugs (NSAIDs). All these treatments aim to reduce the acute inflammatory response that occurs when a muscle is strained.

After a short rest, usually lasting a few days, physical therapy is initiated. Physical therapy consists initially of passive stretching, and exercises are started to restore full range of motion. The earlier that motion can be restored in a painfree manner, the better. In the early stages after a muscle strain, the athlete should not be pushed to the point of fatigue in physical therapy, because this may reinjure the area. Only when the athlete has no noticeable strength deficit, has full range of motion of the hip or knee, and is painfree should he or she return to sports. Allowing athletes to return to their respective sport before they have regained full strength and are painfree can be detrimental to them as it sets them up for repeated injuries.

If an athlete continues to have severe pain for longer than a few days after injury and is unresponsive to the aforementioned treatment options, one must consider obtaining X-rays, which would show bony injury. If no bony injury has occurred and a complete tear is suspected, magnetic resonance imaging (MRI) is the test of choice to show soft tissue injuries, such as tears of muscles, tendons, or ligaments.

Prognosis

The patient outcome for muscle strain is usually very good, especially when only a minor injury has occurred. However, major strains can take a longer time to heal and can result in limited range of motion and weakness for some time. There are relatively few complications from muscle strain, with the most common being reinjury, weakness, and fibrosis. The aforementioned complications most frequently occur with the more severe injuries and rarely occur in less severe, or Grade 1, strain. Reinjury can be prevented by ensuring an appropriate rehabilitation period before the athlete is allowed to return to sport. If a symptomatic area of fibrosis occurs, most often associated with the most severe strains, aggressive stretching should be started and modalities such as ultrasound can be employed.

Summary

Quadriceps strains occur at the myotendinous junction. These injuries are sustained when a forceful contraction of the quadriceps occurs, most often during running or jumping activities. This injury is suspected when there is an abrupt onset of localized pain in the region of the quadriceps. Initial treatment is aimed at decreasing the inflammatory response by the use of NSAIDs, rest, ice, compression, and elevation. Compression and elevation also help by limiting swelling and hematoma formation. Athletes should be transitioned into passive stretching and range-of-motion activities within the first few days after injury. Athletes should be allowed to return to full activity only when there is resolution of pain and swelling, and full muscle strength has been regained.

Jennifer Wood and Jeffrey Guy

See also Strains, Muscle; Thigh Contusion; Thigh Injuries; Thighbone Fracture

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Quadriceps Tendinitis

Quadriceps tendinitis is an overuse injury of the lower extremity characterized by pain over the quadriceps tendon or the superior pole of the patella. The condition is often grouped with other overuse injuries such as patellar tendinitis and

Sinding-Larsen-Johansson syndrome. Both patellar and quadriceps tendinitis are often referred to as "jumper's knee," with studies showing a career prevalence of more than 20% in elite athletes and 40% to 50% in high-level volleyball players. Most cases of jumper's knee are secondary to patellar tendinitis, whereas quadriceps tendinitis is much less common.

Anatomy

The knee is a complex joint that consists of both the femorotibial and patellofemoral joints. It connects the femur to the tibia and fibula and includes the patella (kneecap), which is the moveable bone in front of the knee. The patella tracks along the femoral groove of the knee joint during motion and is encompassed by tendons, acting as one unit to ensure fluid motion. These tendons include the quadriceps and patellar tendons. The quadriceps tendon is an extension of the quadriceps muscles and inserts on the superior pole of the patella. The tendon is composed of three layers: (1) the superficial, (2) the intermediate, and (3) the deep laminae. As the quadriceps muscles contract, a force is exerted along the quadriceps tendon that acts on the superior aspect of the patella. The force is carried through the patellar tendon, which extends from the inferior aspect of the patella to the tibial tuberosity, leading to lower leg extension.

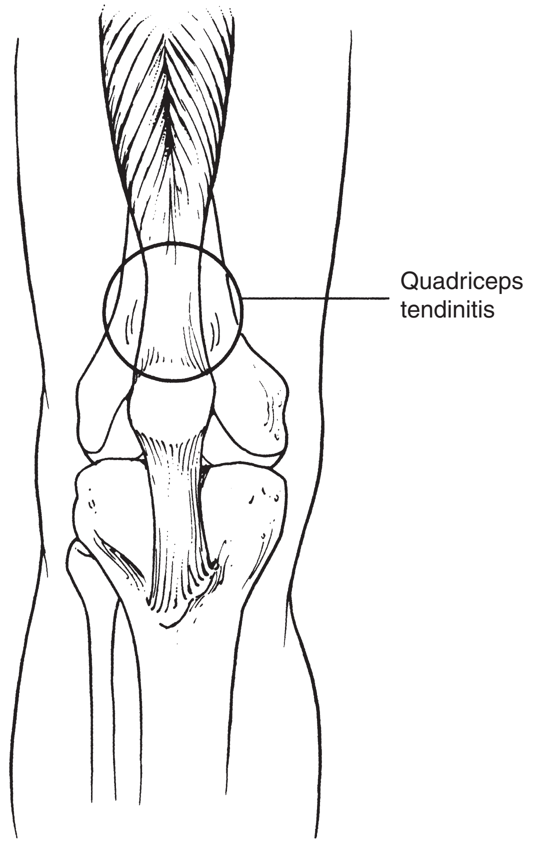

Figure 1 Quadriceps Tendinitis

Notes: Quadriceps tendinitis is an inflammation of the tendon that attaches the quadriceps muscle to the patella. Although less common than patellar tendinitis, it is of substantial concern to the athlete because it affects the all-important extensor mechanism.

Causes

Overuse injuries are common in athletes, with tendon injuries occurring frequently as the tendon takes much of the force and stress of the muscle-tendon unit during exercise. Quadriceps tendinitis is actually a tendinosis consisting of partial tears or degenerative changes to the quadriceps tendon secondary to repetitive forces that surpass the body's ability to repair the damage (Figure 1). This degenerative condition most often occurs in jumping and leaping sports such as volleyball, basketball, soccer, and track-and-field events, all of which place a high amount of repetitive trauma on the tendon. Other studies have shown that risk is increased with higher training volumes, increased training intensity, harder training surfaces, and lower flexibility of the quadriceps and hamstring muscles. Male athletes are also about twice as likely as females to develop unilateral jumper's knee, and the greater force generated by males when jumping has been considered the culprit.

Clinical Evaluation

History

Patients will complain of pain over the anterior aspect of their knee and focused at the superior pole of the patella. The pain may be gradual or abrupt at onset, but frequently these injuries have an insidious onset. The pain becomes worse with athletic activity and is amplified with resisted knee extension or passive hyperflexion of the knee. A classification for severity of jumper's knee consists of four stages. In Stage 1 pain occurs after practice or a game, while in Stage 2 pain is also present at the beginning of activity and remits after warm-up. Stage 3 is increasingly more severe as pain remains during activity, limiting the athlete's ability to participate in sports. Finally, Stage 4 represents complete tendon rupture.

Physical Exam

On examination, assessment is focused over the lower extremities, starting with a careful inspection of the joints to assess for swelling, bruising, or warmth. The contour and shape of the leg muscles, especially the quadriceps, should be carefully assessed to evaluate for decreased muscle bulk or wasting. Range-of-motion testing may provide diagnostic clues if discomfort with full passive flexion is noted. Next, palpation of the knee joint and surrounding landmarks is done. With quadriceps tendinitis, point tenderness over the quadriceps tendon and/or the superior pole of the patella is elicited. Pain is further reproduced with resisted knee extension. Additionally, the knee joint is assessed for stability, and lower extremity strength and neurovascular testings are completed.

Diagnostic Tests

History and physical exam are often sufficient to make the diagnosis. X-ray imaging is usually negative and serves more to rule out other etiologies. For example, in adolescent athletes, multipartite patellae, which can have a similar presentation, can be ruled out via X-ray imaging. In chronic cases, degenerative changes at the patellofemoral joint may be indicated on X-ray. More advanced and costly imaging, such as magnetic resonance imaging (MRI), should be reserved for unclear etiologies, failure of conservative management, and/or worsening pain or new symptomatology.

Treatment

Conservative management is the mainstay of treatment, focusing on stopping the offending activity until symptoms subside, pain management, and a stretching and strengthening program. This approach is often successful with complete recovery of the athlete. However, the more severe the case, the less likely conservative management will be successful. Conservative management is most often successful for Stage 1 and Stage 2 cases, while Stage 3 cases usually require an extended rest period and reduction in training and playing time for good results to be achieved. Studies have indicated that up to half of the patients with Stage 3 cases will fail conservative management, which may necessitate surgical intervention, depending on the athlete's desire to participate in his or her sport at a high level and on the athlete's future goals. If quadriceps tendinitis goes untreated and more strain is put on the tendon, it could potentially lead to tendon rupture. Surgical intervention is indicated for this scenario.

Nonsurgical Treatment

Initial treatment for quadriceps tendinitis consists of cessation of the offending activities, pain management, icing, stretching, and progression through a strengthening program focusing on exercises for the quadriceps and hamstrings. Local corticosteroid injections should be avoided as they could lead to tendon degeneration and increased risk of tendon rupture. Conversely, the effectiveness of extracorporeal shockwave therapy (ESWT) has recently been considered given its use in treating other tendinopathies. ESWT is thought to create an environment more suitable for tissue healing. More research needs to be done in this area, and the Food and Drug Administration (FDA) has not yet approved the use of ESWT for quadriceps tendinitis.

Surgical Treatment

Surgery is used for cases refractory to nonsurgical therapy, usually after completion of a 4- to 6-month trial period of conservative management, and for complete tendon rupture. The purpose of surgical intervention is to induce healing at the bone-tendon junction, debride degenerative tissues, and remove abnormal bone. Postoperative management is a gradual process, focusing on regaining range of motion followed by recovery of muscle strength. If these goals have been achieved, the athlete may gradually resume full sports participation at 6 months postoperatively, although the previous level of play is generally not achieved until after 12 months. There are a variety of surgical techniques used, and studies report varying surgical outcomes.

Prevention of Injury

Injury prevention is essential as quadriceps tendinitis can require a long recovery period and a decrease in level of play. Prevention should be the focus of athletes and coaches, especially those participating in high-risk sports. Prevention involves maintaining quadriceps strength and flexibility. Off-season conditioning programs should focus on strength training, and individual athletes should be eased into the sport/training program. The athlete and/or coaching staff should keep potential extrinsic and intrinsic risk factors in mind, such as the training surface. At the onset of pain, therapy should not be delayed because an optimal outcome is more likely to occur with early intervention.

Return to Sports

Certain guidelines should be followed before allowing an athlete with quadriceps tendinitis to participate again in his or her sport. The guidelines consist of a graduated process to full participation. First, the athlete should have full range of motion of his or her affected lower extremity. Second, appropriate quadriceps strength must be exhibited. Quadriceps on the affected side must be at 80% to 85% of the expected strength, which can be evaluated by comparing it with the unaffected side. If both legs were involved, then computerized isokinetic testing could be used to confirm strength. When the individual is able to complete functional testing at 70%, he or she can begin participating in sport-specific drills. Once the athlete can perform functional testing at 85% to 90% capacity, he or she can participate in full practice and return to games. This should occur through a stepwise process, starting for only a quarter of the time, then half the time, and so forth. At any point, if the athlete starts to have pain, he or she should refrain from participation.

Susan Bettcher and James Borchers

See also Knee Bracing; Knee Injuries; Knee Injuries, Surgery for; Tendinitis, Tendinosis

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Racquetball and Squash, Injuries in

Racquetball and squash are popular sports played around the world by recreational and elite athletes alike. While neither is an Olympic sport, both have world championship competitions and are played at international events such as the Pan-Am Games. Racquetball and squash games take place on a court surrounded by four walls and involve using a racquet to hit a rubber ball off the front wall of the court. A racquetball court measures 40 feet (ft) long by 20 ft wide by 20 ft high. In comparison, a squash court measures 32 ft long by 21 ft wide.

Athletes who play racquetball or squash are prone to certain types of injuries due to the specific demands of their sport. Because of the fast-paced nature of both games and the occasional, unpredictable ricochet of the ball during play, eye and facial injuries are the two most common injuries suffered in these sports. Also seen are upper extremity injuries such as elbow and wrist sprains, shoulder sprains, lateral epicondylitis, and de Quervain tenosynovitis. Common lower extremity injuries include ankle sprains, Achilles rupture, knee ligament injuries, and meniscal tears.

Eye Injuries

Eye injuries are caused by either the racquet or the ball striking the eye during play. Shots that frequently lead to injury include hitting the ball off of the back wall. This shot is hit with force so that it has enough energy to hit off of the front wall; however, if a player misplays the ball or steps into its trajectory, the ball can accidentally hit the player in the eye. Another frequent cause is when a player turns to see the hit of the opponent playing behind him or her and the forward-traveling ball hits the front player in the eye. In squash, eye injuries are generally more severe because the ball is smaller and can easily fit into the eye socket. Almost all eye injuries occur when the player is not wearing eye protection; therefore, wearing eye protection is highly recommended.

A wide range of eye injuries can occur from participation in racquetball or squash, but the two most common eye injuries seen are hyphemas and corneal abrasions. A *hyphema* is a collection of blood in the anterior chamber of the eye, often caused by trauma. Hyphemas will cause blurry vision, pain, and increased flow of tears. When the ball (or racquet) hits the eye, the eye momentarily undergoes an increase in internal pressure due to the distortion of the shape of the eyeball on impact. This can cause a tear in the small blood vessels and leads to bleeding, with the blood collecting in the anterior chamber of the eye. A severe bleed can fill most of the anterior chamber of the eye. This is sometimes called an "eight-ball hemorrhage" because the eye appears black. While the blood itself is not harmful to the eye, it can obstruct the movement of fluid within the eye and cause glaucoma. It is also important to consider that the eye has sustained a force strong enough to cause injury and could also have other internal injuries that are not immediately obvious.

Therefore, prompt evaluation by an ophthalmologist is recommended.

Treatment for minor hyphemas includes keeping the head elevated (do not lie flat) so that the blood pools to the bottom of the eye, avoiding straining, and using eye drops prescribed by a physician to reduce intraocular pressure. Severe hyphemas will require frequent monitoring by an ophthalmologist. Eventually, the blood from the hemorrhage will resorb. It usually takes a few weeks to see complete resolution.

A *corneal abrasion* is a common eye injury that occurs when a part of the cornea is scraped (or scratched) away. In racquetball and squash, this usually occurs when the ball or racquet makes contact with the eye or when one player accidentally pokes the other in the eye. A corneal abrasion is painful and will cause tearing. Photophobia (increased sensitivity to light) and feeling as though there is something in the eye are also common symptoms. The abrasion usually heals without a problem. Treatment includes eye rest and not using contact lenses until the abrasion is healed. Most minor abrasions heal in 24 to 48 hours. Larger abrasions can take up to 1 week to heal. Larger abrasions may be treated with antibiotic drops to help prevent infection.

In squash, the ball is smaller and firmer and therefore can cause more severe eye injuries such as globe rupture or retinal detachment. *Globe rupture* occurs when the outer membrane of the eye is disrupted due to trauma. This is a full-thickness tear in the membranes of the eye and is a very severe injury. The eye will most likely be disfigured as a result of the injury, and it will be obvious to others that medical attention is needed. Symptoms include a significant decrease in the ability to see and double vision. Globe rupture is an emergency and requires immediate medical attention.

Retinal detachment is also an emergency that requires prompt medical treatment. Trauma to the eye can cause the retina to peel away from the underlying supportive tissues. Symptoms include a sensation of flashing lights, floaters, vision loss, and distortion of vision. It is crucial to seek help right away because quick medical attention can be vision sparing. The best prevention for all eye injuries is to wear proper eye protection endorsed by the Canadian Standards Association (CSA) or American Society for Testing and Materials (ASTM). Wearing eye protection can help prevent almost all eye injuries incurred in racquetball and squash. Unfortunately, protection is not worn by all players, especially novice players.

If the ball or racquet misses the eye but strikes the face, it can cause facial lacerations or contusions (bruises). Frequently, this occurs to the player who gets in the way of his or her own racquet. While most lacerations are not serious enough to require medical treatment, larger lacerations require sutures to ensure proper healing.

Upper Extremity Injuries

Common upper extremity injuries suffered by racquetball and squash players include elbow and wrist sprains, shoulder separation, lateral epicondylitis, and de Quervain tenosynovitis. Shoulder separation, or *acromioclavicular (AC) separation*, can occur when a player's shoulder takes the brunt of the impact when diving or hitting a wall while going after the ball. An excessive force placed on the shoulder can cause a disruption in the ligaments that connect the acromion to the clavicle (collarbone). Severe separations can cause a deformity where the collarbone sticks out more prominently under the skin. Most separations heal with rest, but a severe separation requires surgical correction.

As with other racquet sports such as tennis, frequent squash and racquetball play can lead to overuse syndromes such as *lateral epicondylitis* (tennis elbow). This is the most common upper extremity injury seen in both racquetball and squash players. Frequent backhand shots can cause an inflammation of the muscles that extend the wrist. These muscles attach to the outer part of the elbow and cause pain in that location. Another upper extremity overuse injury is *de Quervain tenosynovitis*, an inflammation of the tendons that causes pain in the wrist right below the thumb. Pain is increased when gripping or turning the wrist. Injection of steroids into the area of inflammation is the appropriate treatment if rest does not relieve the pain.

Lower Extremity Injuries

Both games require quick changes in direction and sharp cuts. As with any activity of this nature, ankle sprains, knee ligament injuries, meniscal tears, Achilles tendon rupture, gastrocnemius (calf muscle) tear, and lower back strains can occur. It is impossible to tell with what frequency these injuries occur because most are minor and the injured player does not seek care from an emergency department or a physician. These injuries, if severe, could sideline a player for several months.

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See also Achilles Tendon Rupture; Acromioclavicular (AC) Joint, Separation of; Ankle Sprain; Meniscus Injuries; Shoulder Dislocation; Shoulder Subluxation; Tennis Elbow

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Referred Pain

Referred pain is a rather broad term used to describe a phenomenon where pain is perceived at a site adjacent to or even distant from the site of pathology. There is no universally accepted definition, and hence different authors in the medical literature have used the phrase to describe different clinical entities that may present to the sports medicine clinician.

One of the most well-known examples of referred pain is the pain of *angina,* which can be perceived not only in the chest but can *radiate* to the jaw, to the back, or down the arm. This type of visceral pain, where an internal organ is injured, is a relatively common cause of referred pain in general medicine. *Radicular pain*, in which a spinal nerve root is inflamed, is another commonly seen example of referred pain.

Referred pain can also be seen in chronic musculoskeletal dysfunction (specifically in myofascial pain syndromes), as a manifestation of joint pain, and also in association with peripheral compressive neuropathies. This is not an exhaustive list. This entry describes the various clinical scenarios that might present to the sports medicine clinician.

It is always incumbent on the sports medicine clinician to keep the entities of referred pain in mind when developing a differential diagnosis in the treatment of an individual athlete. What at times may appear to be a straightforward biomechanical issue can, at its root, be a more complex phenomenon involving referred pain from a distant site of pathology. Due diligence in eliciting an exhaustive history and conducting a thorough physical exam is of paramount importance. Finally, it is always important to revise one's diagnosis if the patient is not achieving the treatment goals within the anticipated time frames. Referred pain entities are a not infrequent cause of treatment failures.

An Example

Elbow overuse injuries in an athlete can provide an example of the type of differential diagnostic thinking the clinician should practice.

Tennis elbow is, indeed, frequently related to local soft tissue inflammation and degeneration (e.g., lateral epicondylitis). However, pain of the lateral aspect of the elbow and forearm can relate to intraarticular dysfunction (e.g., osteochondritis dissecans of the capitellum). Moreover, it can also be seen in some clinical entities of referred pain. For instance, cervical discogenic neck pain can present with lateral arm pain. Radial tunnel syndrome can mimic lateral epicondylitis very closely, but in the former, the pain generator is not a tendinosis but rather a compression neuropathy of the radial nerve. Trigger points, seen in mysofascial pain syndromes and described in more detail below, can often be found in the wrist extensors or the triceps and give rise to radial-sided elbow pain that can resemble classic tennis elbow.

Types of Referred Pain

Visceral Pain

Pain in the viscera can be perceived as originating from a site distant from the affected organ. The location of the pain is typically the cutaneous dermatome sharing the same spinal cord level as the visceral input. As an example, the pain of cholecystitis (inflammation of the gallbladder) can occasionally be perceived in the scapula, since nociceptive inputs from the gallbladder enter the spinal cord between T5 and T10, which is the dermatome overlying the scapula.

Visceral pathology resulting in referred pain can account for pain in almost any area of the presenting athlete's body. However, some of the more notable examples encountered by the sports medicine clinician include the following:

- *Anginal pain*, previously mentioned, is an exceedingly important type of referred pain to keep in the differential diagnosis, especially when treating middle-aged or older athletes. The pain is typically described as constant, heavy, and radiating across the left chest wall, into the jaw, and down the left arm. Anginal pain has all too frequently been attributed to musculoskeletal chest pain or even reflux disease. Maintaining a high degree of suspicion in the patient with risk factors is of paramount importance given the high degree of morbidity and mortality seen in angina.
- *Kehr sign* is considered a classic example of referred pain. It is the onset of acute pain in the shoulder related to the presence of blood or other irritants in the peritoneal cavity. It is classically related to a ruptured spleen, in which case the pain is most commonly experienced in the left shoulder, but the sign has been used to describe pain in either shoulder with diaphragmatic or intraperitoneal pathology other than a ruptured spleen—for example, an ectopic pregnancy.
- A *pneumothorax* or *pneumomediastinum* can present as back or anterior chest pain. The pain is typically diffuse and less easily localizable than that associated with a focal musculoskeletal injury. There is typically an element of associated respiratory distress seen in the patient under evaluation.
- *Pelvic* or *testicular masses* sometimes present as chronic groin pain with radiation into the hip or upper thigh.

Peripheral Compression Neuropathies

Several peripheral neuropathies, discussed in detail in other entries in this encyclopedia, can present with pain distal to the area of pathology as the chief complaint. The typical mechanism is compression of a nerve or nerves, giving rise to distal sensory and motor pathology. Below are some examples:

- *Thoracic outlet syndrome* can present with pain in the shoulder, arm, or hand (typically ulnar-sided pain) as a result of compression of the nerves passing from the neck and thorax through the "thoracic outlet," a space defined by the rib cage and the clavicle. Various structures can be implicated in the impingement; the presentation of pain distal to the impingement is a classic example of referred pain.
- *Meralgia paresthetica* is a painful condition of the proximal, anterior thigh seen with a mononeuropathy of the lateral femoral cutaneous nerve. There is typically focal entrapment of the nerve at the site of the inguinal ligament, and distally, pain will develop over the anterolateral thigh.
- *Carpal tunnel syndrome* is a well-known compression neuropathy of the median nerve as it passes through the carpal tunnel of the wrist. The presenting complaint is often pain in the first three digits and the radial aspect of the fourth in the affected hand (see Vol. 1, pp. 238–241).
- *Guyon tunnel syndrome* can affect the bicyclist. Pressure from bicycle handlebars can cause a compressive neuropathy of the ulnar nerve in the Guyon canal of the wrist, resulting in motor and sensory findings in the fifth and fourth digits of the hand.
- *Tarsal tunnel syndrome* is a painful condition of the foot in which the posterior tibial nerve is impinged and compressed as it travels through the medial ankle in what is known as the tarsal tunnel. It resembles in many ways the compressive neuropathies of the medial and ulnar nerves of the hand and wrist. Symptoms include burning pain and numbness in the heel and plantar surface of the foot.
- *Piriformis syndrome* can be considered in this same classification. In classic piriformis syndrome, the piriformis muscle of the patient's hemipelvis will become constricted, and impingement of the ipsilateral sciatic nerve will develop. Classic sciatica can develop and may

be difficult to distinguish from radicular pathology of the lumbosacral spine (see Vol. 3, pp. 1098–1100).

Joint Pain

Focal articular dysfunction can sometimes present, somewhat paradoxically, with pain perceived less in the affected joint than in an adjacent joint. This situation is most often encountered in the pediatric population.

The pain of hip pathologies such as Legg-Calvé-Perthes disease and slipped capital femoral epiphysis not infrequently originally manifests as knee pain.

The wise clinician should remember the classic dictum to examine the joints both proximal and distal to the presenting complaint when doing a thorough examination. In the setting of a new patient, particularly a pediatric one, complaining of knee pain, a brief but focused examination of the hip is important.

Cervical, Thoracic, and Lumbosacral Dysfunction

Radiculopathies, or inflammations of spinal nerve roots, are rather common causes of referred pain. Radiculopathies are characterized by pain that appears to radiate out from the spine down an arm or leg or across the torso. Causes of radiculopathies include deformities of the intervertebral disks or the vertebrae themselves, where bone or disk material can impinge on the spinal nerve root, evoking pain in a characteristic pattern depending on the level of impingement.

A thorough understanding of associated dermatomes, myotomes, reflex patterns, and muscle innervations is crucial for the clinician evaluating a patient with a possible spinal radiculopathy. For instance, pain that radiates down the leg into the lateral foot (especially when provoked by a cough or trunk flexion) can be characteristic of disk pathology at the L5-S1 level.

Myofascial Pain Syndrome

This is perhaps the most complicated and, to most clinicians, least familiar type of referred pain discussed in this entry.

Myofascial pain syndrome is a common painful muscle disorder caused by myofascial trigger points. It is sometimes confused with fibromyalgia but is a distinctly different disorder. It has been written about most extensively in the osteopathic and physiatry medical literature.

Patients typically present with localized, persistent pain that often results in decreased range of motion of the muscle in question. The athlete may have a history of an acute injury in this area or a history of a more chronic, repetitive stress injury. Postsurgical myofascial pain is seen as well and is often attributed to surgical scars and tissue under tension after surgery.

The patient will present with so-called trigger points (TrPs), which can produce referred pain as well as motor and even autonomic dysfunction in characteristic patterns. TrPs are circumscribed nodules, approximating 1 centimeter in diameter, found in muscle; they are palpable, taut bands, and when they are pressed, the patient will recognize the tenderness as the familiar pain for which he or she is presenting for evaluation.

On examination, the pain elicited on palpation is referred in a pattern characteristic of the TrPs for that muscle. Palpation often also will elicit a local twitch response. There can be painful limitation of range of motion when attempting to stretch the muscle, and there is often some weakness of the muscle. Neurologic deficits are typically absent on physical examination.

Myofascial trigger responses are consistent from patient to patient. The points have been most extensively and systematically evaluated by the physicians Janet Travell and David Simons, who essentially mapped the patterns of TrP location and radiation. Their textbook is a classic in the field and gives the location of TrPs for nearly every skeletal muscle in the body, along with associated patterns of referred pain (see the Further Readings).

There is still some considerable controversy over the methodology for consistently diagnosing TrPs and over the theory of how TrPs arise and why they produce specific referred pain patterns. Several mechanisms have been proposed, but scientific evidence is lacking.

Once the TrPs have been identified and other pathologies in the differential diagnosis excluded, treatment of the myofascial pain can be pursued. The long-term clinical efficacy of the therapies has not been established. Multiple modalities can be used, including pharmacology, acupuncture, physical therapy, osteopathic manual medicine techniques, and massage. The "spray-and-stretch" technique and injections of TrPs are two of the more common techniques.

The spray-and-stretch technique uses a topical cold spray (e.g., ethyl chloride) and involves passively stretching the affected muscle while simultaneously spraying the area with the spray. It is thought that the temporary, mild anesthesia effected by the spray allows the muscle to be passively stretched to its normal length, thus inactivating the TrPs and resolving the referred pain.

For TrP injections, small-gauge needles are used, and a local anesthetic (e.g., lidocaine) or sterile saline is injected into the palpated TrPs of the affected muscle in an attempt to inactivate them. As with all injections, attention to procedural detail will minimize complications such as infection or, worse, pneumothorax.

James Patrick Macdonald

See also Cervical and Thoracic Disk Disease; Ulnar Neuropathy

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Renal Injury

The kidney is the most commonly injured intra-abdominal organ in some sports, such as rugby union. Varieties of renal injury include renal trauma and exercise-induced hematuria, which may or may not be traumatic in origin. Renal traumatic injuries may be relatively asymptomatic, even with repeated blows, such as in boxing, or they may result in renal contusions, causing microscopic or gross hematuria.

Occult Hematuria

Hematuria is a common condition in the general population. Occult hematuria without radiographic evidence of injury is extremely common in several sports and is often specifically attributed to *exercise-induced hematuria.* Occult hematuria is defined as greater than three red blood cells (erythrocytes) visualized per high-powered field on microscopy. Estimates vary between 13% and 38% as to the prevalence of occult hematuria in an otherwise healthy adult population. Athletic populations are generally considered to have a much higher prevalence. One study reported swimmers, track-and-field athletes, and lacrosse players to have an incidence of around 80% and football players and rowers, about 55%. Among boxers, 73% were noted to have occult hematuria after a fight.

Pathophysiology

There are many proposed mechanisms for non-traumatic hematuria. Etiologies can be best conceptualized by considering the source of the blood from the urethra proximally to the bladder, the ureters, and the kidneys themselves. During exercise, renal plasma flow may decrease from the normal 700 to 200 milliliters (ml)/minute, with the decrease being proportional to the intensity of the exercise. Blood is shunted to skeletal muscle by vasoconstriction of the renal blood vessels. Subsequently, the functional unit of the kidney, the nephron, can suffer hypoxic damage, which can result in increased glomerular permeability and hence an increased frequency of erythrocytes being excreted into the urinary tract. The relatively greater vasoconstriction in the efferent glomerular arterioles may also increase filtration pressure and achieve stasis of blood flow in the glomerular capillaries. These phenomena can also increase the rate of erythrocytes being excreted.

Exercise can also induce trauma to the bladder; for example, bladder contusions are seen on performing cystoscopy after a distance-running event. In this circumstance, the posterior bladder wall is believed to ram the thicker, rigid bladder base. Cumulative impacts likely result in contusion, particularly when the bladder is empty.

Cyclists can traumatize their urethra or prostate due to the bicycle seat's position, especially if this is placed preferentially high to enhance performance.

It should be noted that occult or exercise-induced hematuria should resolve after the athlete recovers from strenuous exercise. If this resolution does not occur, a broader differential diagnosis should be entertained.

Renal Traumatic Injury

Kidney trauma from a direct blow is particularly common in football and rugby, ice hockey, soccer, horseback riding, gymnastics, boxing, sledding, and skiing. Blunt trauma from a direct blow is the most common mechanism, though penetrating injury can occur in sports involving high velocity or force. Younger patients require special attention, as renal injury is more common than splenic or hepatic injury. Up to 30% of renal trauma in children is related to sports. This may be caused by a proportionally larger kidney size or the lack of musculoskeletal protection. The kidney is well protected by the ribs, abdominal muscles, back muscles, and supporting fascia. However it is mobile, making it susceptible to injury by sudden deceleration forces or puncture by a fractured rib.

Clinical Evaluation

A thorough history and physical examination are warranted in the evaluation of hematuria. If not witnessed, an explanation of the mechanism of injury is essential when blunt abdominal trauma is suspected. If the hematuria is gross, specific questioning about the onset with regard to initiating micturition can help determine if the source is the urethra (immediate), the bladder neck/prostate (terminal), or the ureter or kidney (throughout). Clots indicate nonglomerular bleeding, large thick clots suggest a bladder source, while thin stringy clots are more common with ureter sources.

Physical exam technique should follow the traditional medical model of inspection, palpation, percussion, and auscultation. Inspection can reveal contusion or abrasion of the flanks in particular, but it should include visualization of the abdomen, the back, and the genitalia to exclude other signs of injury. Palpation of either flank may reveal tenderness: The kidneys are "ballotable," meaning bimanual palpation with either hand on opposite sides of the torso reveals an awareness of a floating kidney moving between the two. Lumbar spine transverse process or rib fractures may be suspected with tenderness noted on palpation of these structures. Percussion can help determine the presence of peritonitis, and auscultation can elicit bowel sounds unless an ileus has developed and the intestines have ceased to function. Hemodynamic instability may be present and can be ascertained from vital signs such as elevated heart rate and diminished blood pressure.

Urinalysis and Laboratory Evaluation

The laboratory work-up begins with a urinalysis. Urine dipstick urinalysis for red blood cells has been noted to have a sensitivity of 91% to 100% and a specificity of 65% to 99%. Microscopic evaluation of the urine for erythrocytes is the next step, with abnormally shaped erythrocytes suggesting a glomerular source and intact erythrocytes suggesting a nonglomerular source.

A repeat urinalysis 24 to 72 hours after the initial episode of hematuria is required. If the hematuria clears after 24 to 72 hours and the patient is less than 40 years of age, then a diagnosis of exercise-induced hematuria can be made. Further evaluation is required in the presence of a concerning history or physical exam if the patient is older than 40 years, has recurrent episodes of hematuria, or has not engaged in vigorous exercise. An algorithm outlining the evaluation of the athlete with hematuria helps guide the diagnostic process (Figure 1). It should be noted that 2% to 4% of traumatic renal injuries do not demonstrate hematuria.

Imaging

Computed tomography (CT) scan has replaced intravenous urography as the imaging study of choice in the hemodynamically stable patient with blunt renal trauma. An injury to the kidney is shown by CT in the image on page 1207. CT can provide precise delineation of a laceration, determine the presence of a hematoma or retroperitoneal bleeding, and indicate the presence of urinary extravasation or devascularized renal parenchyma. CT is indicated in adult patients with (a) penetrating injury, (b) gross hematuria, (c) microscopic hematuria with shock, or (d) suspected major associated intra-abdominal injury. The current practice recommendation is to image all children with

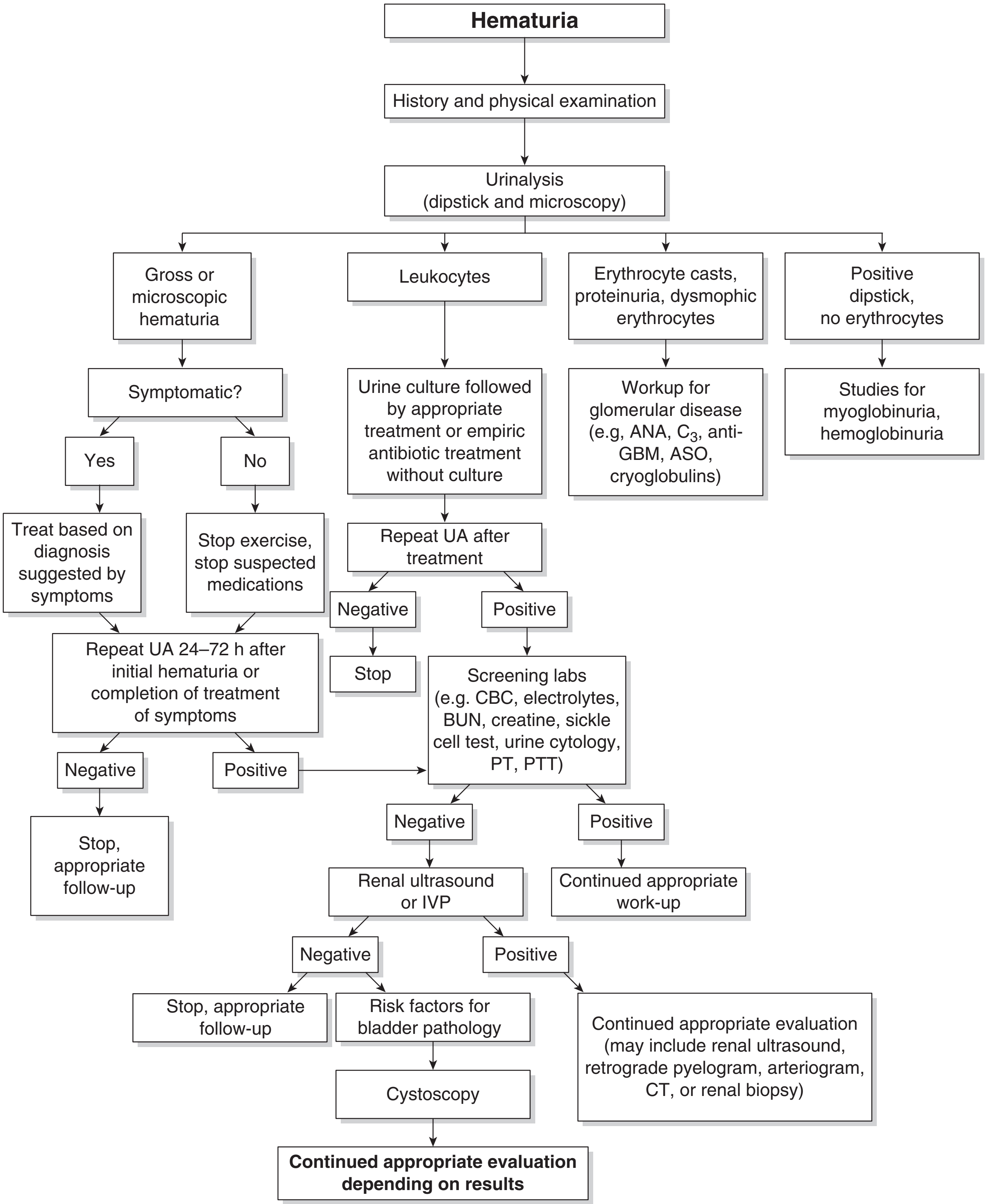
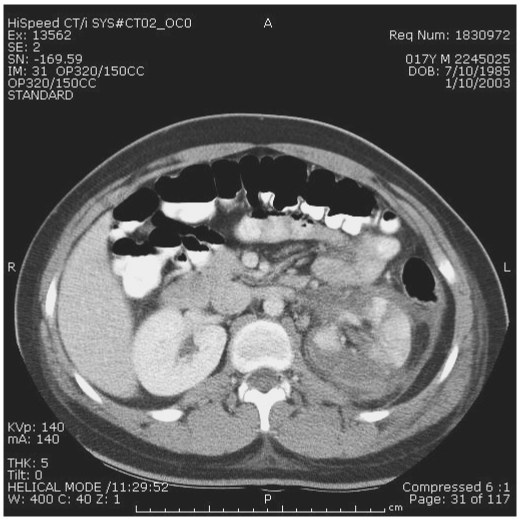


Figure 1 Algorithm for the Evaluation of Hematuria

Source: Clarke FC, Hunt JJ, Sevier TL. Renal injury in sport. *Curr Sports Med Reports*. 2003;2:103–109. Used with permission.

Note: ANA = antinuclear antibody test; anti-GBM = antibodies for glomerular basement membrane; ASO = antistreptolysin O test; BUN = blood urea nitrogen; C3 = complement; CBC = complete blood count; CT = computed tomography; IVP = intravenous pyelogram; PT = prothrombin time; PTT = partial thromboplastin time; UA = urinalysis.



CT scan of injury to left kidney

Source: Courtesy of David Mooney, M.D., Children's Hospital Boston.

blunt trauma and hematuria regardless of blood pressure or degree of hematuria.

Management

Management of the athlete with renal trauma, of course, depends on the severity of injury. The goal is to preserve functioning of the renal parenchyma and minimize morbidity. Injury severity is graded based on the American Association for the Surgery of Trauma organ injury severity scale for the kidney, which has been validated to determine the need for surgical repair or nephrectomy. One reported series indicated that of 59 sports-related kidney injuries, 5 required surgical intervention and 2 resulted in nephrectomy.

Gross hematuria should always be evaluated in a hospital setting. The majority of sports-related renal trauma cases involve contusion and can be managed conservatively with observation, bed rest, and supportive therapy. Nonoperative management is appropriate as long as the athlete is not in hypotensive shock, there is no expanding hematoma, and there is no free extravasation of urine by intravenous contrast CT. Nonoperatively managed athletes with renal contusion should be observed until the hematuria clears, and they should be excluded from contact sports for 6 weeks.

Return to Sports and Prevention

Once exercise-induced hematuria has resolved, there is no contraindication to a return to sports. There is no evidence that repeated episodes of exercise-induced hematuria lead to urorenal complications. Athletes should be encouraged to stay hydrated and not to completely empty their bladder before vigorous activity.

Complete healing of traumatic renal injury is essential before return to sports. Most renal injuries heal within 6 to 8 weeks. Microscopic hematuria may persist for 3 to 4 weeks after injury. Return to contact or collision sports may be delayed 6 to 12 months in athletes with more extensive renal injuries. Some athletes may choose not to return to sports.

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See also Abdominal Injuries

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Resistance Training

Resistance training is one of the pillars of exercise that is essential for overall health and fitness as well as for athletic performance. Typically, resistance training is referred to as weight training or "lifting." Resistance training is much more than just biceps curls and shoulder presses with dumbbells. This entry briefly discusses the body's adaptations to resistance training, as well as the sources of resistance that the body may use.

Resistance Training Adaptations

Resistance training adaptations are both *acute* and *chronic*. Acute responses to resistance training occur primarily in the neurological, muscular, and endocrine systems. Chronic responses to resistance training are seen in the muscular, skeletal, endocrine, cardiovascular, and neurological systems. Anthropometric (body composition) adaptations are also seen as chronic adaptations to resistance training.

Acute and Chronic Neurological Adaptations

When a force is applied to a muscle, a signal is transmitted that activates the muscle cells. When performing resistance training, the number and intensity of signals that are transmitted are increased until the muscle fatigues. The two neurological factors that govern muscle force are motor unit recruitment and rate coding. Motor unit recruitment is simply the size of the muscle force created by the muscle contraction for a given task. For example, fewer motor units in the biceps brachii muscle are recruited when performing a biceps curl with a 10-pound (lb; 1 lb = 0.45 kilogram [kg]) dumbbell than with a 50-pound dumbbell. According to the kinesiologist R. N. Enoka, motor unit recruitment is based on the size principle, which states that the motor units that recruit slow-twitch fibers recruit fewer fibers than the motor units that recruit fast-twitch fibers. Rate coding governs motor unit firing. During resistance training, the muscles fatigue with each repetition of a given movement pattern, and as a result, the rate coding becomes impaired and the firing sequence becomes less and less precise.

Chronic adaptations would result in a more efficient sequence of recruitment of motor units, making the muscle less apt to fatigue from neuromuscular factors. Other chronic adaptations to the neurological system include increased motor unit firing and decreased co-contraction of the antagonist muscles. Co-contraction takes place when both agonist and antagonist muscles fire at the same time. The decrease in the co-contraction of antagonist movement when the agonist muscles are being called on for work allows for greater movement efficiency.

Acute and Chronic Muscular Adaptations

One of the acute effects of muscle during resistance training is the depletion of metabolic substrates, such as creatine phosphate and glycogen. Due to the depletion of these two fuel sources during resistance training, muscle power production decreases. Another significant acute muscle adaptation during resistance training is the intramuscular elevation of hydrogen. This results in a "burning" sensation in the muscles on multiple repetitions. The elevation of hydrogen ions in the muscle results in decreased intramuscular pH. Chronic adaptations from resistance training include increased cross-sectional size of the muscle fibers, also known as muscle hypertrophy. Hypertrophy of muscle occurs in Type I and Type II muscle fibers; however, Type II muscle fibers have a greater response. Manipulation of volume and intensity of resistance training will cause more or less hypertrophy to these respective muscle fiber types. The chronic adaptation of increased cross-sectional size of the muscle fibers results in an increase of muscle strength and power. Another chronic adaptation to the muscles, which has been proven in animals but not yet in humans, is a phenomenon called *hyperplasia*. This is when the number of muscle fibers increases. The resulting hypertrophy and possible hyperplasia of muscle fibers cause a relative increase in protein synthesis. This is essential for the repair of muscle fibers in acute response to resistance training.

Acute and Chronic Endocrine Adaptations

There are two major types of hormones produced by the pituitary glands that respond to resistance training: *protein* and *steroid hormones*. Growth hormones and insulin are major protein hormones, while testosterone and estrogen are major steroid hormones. Resistance training acutely increases the concentration and release of both anabolic and catabolic proteins and steroid hormones. Growth hormones, testosterone, and insulin are anabolic hormones that facilitate the growth and recovery of muscle tissue on completion of a resistance training session. However, equally muscle-degrading hormones, or catabolic hormones, are released during and after resistance training. The increase of cortisol, epinephrine, and norepinephrine secretion during resistance training can have positive short-term effects, but the long-term effects are negative. Higher volume and intensity of resistance training routine will elicit a greater release of epinephrine. Therefore, it is prudent to eat proteins and carbohydrates pre- and postresistance training to prevent a catabolic effect from cortisol, epinephrine, and norepinephrine. Chronic adaptations to the endocrine system include an increased resting level of testosterone and increased sensitivity of tissue response to the release of protein and steroid proteins.

Acute and Chronic Skeletal and Body Composition Adaptations

Adaptations of the skeletal system do not occur acutely but rather over the long term. Recent research has indicated that bone mineral density (BMD) increases or is maintained in postmenopausal women who regularly participate in resistance training. Generally, postmenopausal women are at greatest risk of osteoporosis, referred to as the demineralization of bone. It would take 6 to 8 weeks of regular resistance training to see a positive improvement in BMD.

Body composition changes are seen as a chronic adaptation to resistance training. Body composition is broken down into *fat mass* (subcutaneous fat) and *fat-free* mass (bones, muscle, etc.). Fat-free mass is primarily increased due to muscle hypertrophy from regular resistance training. As a result, the energy expended by the body to maintain the muscle mass is greater (increased caloric expenditure), causing a decrease in fat mass. The connective tissue in the dermis also increases its elasticity, making the skin tighter and resulting in an overall younger-looking body. The length of time for these chronic adaptations to be seen will vary depending on a person's gender, chronological age, training age, and genetic makeup.

Modalities of Resistance Training

When a person says that he or she does resistance training, people assume that the person uses "weights." However, the means used to produce acute and chronic adaptations of resistance training may vary significantly. The means that will be discussed within this entry are not the only types, but they are the ones most frequently used. The major modalities are

- gravity,
- inertia,
- fluid resistance, and
- elastic resistance.

Gravity

Every object has mass; therefore, the earth's gravity will affect each object's density and mass. When people say that they use weights for training, they are actually referring to the gravitational forces affecting an object that is shaped ergonomically for ease of use and repetitive use. According to the principles of biomechanics, resistance training with "weights" varies significantly from training with "machines." The key principle is that all forces acting on an object used for resistance training act in a downward direction.

Inertia

The basic physics learned in grade school can be applied to resistance training. Newton's first law states that unless an unbalanced force is applied, a body in motion tends to remain in motion and a body at rest tends to remain at rest. Newton's second law states that force equals mass times acceleration; therefore, if an object has a small mass, a greater acceleration will have to occur on the object than if the same force were applied to an object with a greater mass. When performing resistance training, the force applied by agonist muscles to a given mass (weights or a body under gravitational forces) at a constant rate is equal to the downward force of gravity on the said mass. Inertial resistance along with gravitational pull act on the mass that is being moved by any type of acceleration. The inertial resistance is equal to the accelerative force applied to the object from the opposite direction. An example of this would be when lifting a barbell off the ground. If the mass of the object is 60 kg, then the initial force applied upward would have to be greater than 60 kg because the initial force must have acceleration to overcome the inertial force as well as the gravitational force. Once the initial force is applied to the object, the amount of force applied does not have to be as great to perform multiple repetitions.

Fluid Resistance

The classic example of fluid resistance training is swimming. The fluid resistance in this case is water. Fluid resistance is also a factor in activities such as cycling, baseball, and golf. These activities are examples of air resistance. The resistance from water and air come in two forms, surface drag and form drag. The friction of the water and the air along with the inertial and gravitational forces create a different dynamic of collective forces to move an object.

Elastic Resistance

Heavy-duty rubber bands, tubing, and springs are forms of elastic resistance. The premise of using elastic resistance is that the greater the stretch of the band or spring, the greater the force needed to overcome the resistance. If the density is too great, the muscle will not be able to complete the full range of movement of a particular exercise. Elastic resistance may be integrated with gravitational resistance as well as fluid resistance to create yet again another variable for the muscle to adapt to.

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Respiratory Conditions

Exercise can be highly beneficial for patients with pulmonary diseases. Proper control can be achieved through control of the environment and the use of medications to allow safe participation.

Asthma

Asthma is a pulmonary condition that involves chronic inflammation of the airways, which leads to bronchial hyperreactivity or spasm. Symptoms may include wheezing, cough, chest tightness, and shortness of breath. In the United States, asthma is present in about 6% to 7% of the child population, and an estimated 17 million adults have chronic asthma.

The inflammation and spasm of the airways create an obstruction to airflow and thus generate the symptoms of wheezing, cough, and shortness of breath. The degree of airflow obstruction can be measured with a peak flow meter, or spirometry. These instruments can measure the volume and speed of airflow, which can be compared with the standards for age and height to assess any deficits. Patient complaints of symptoms of tightness, wheezing, or cough are important in making the diagnosis of asthma even if these symptoms are not present at the time of examination. The diagnosis of asthma is confirmed when the airflow obstruction can be reversed by bronchodilator medication and repeat spirometry or if peak flow measurements normalize. The severity of asthma is classified on a scale from mild to severe according to the frequency of symptoms, lung function, and the medications needed to maintain control.

Chronic asthma results from changes in the cells lining the bronchial tubes. These cell changes cause edema, inflammation, mucus production, and spasm of the bronchial tubes. Allergens are a common trigger of asthma flare-ups, especially in patients with a personal or family history of allergic skin disease. Other asthma triggers may include hot or cold exposure, smoke, pollutants, food allergies, molds, stress, or exercise.

Exercise-Induced Asthma

Exercise-induced asthma involves a temporary airflow obstruction triggered by physical exertion. The symptoms are similar to those experienced in asthma but are induced only by exercise and improve at rest. Exercise-induced asthma affects approximately 12% to 15% of the general population and up to 40% of allergy sufferers. Symptoms of wheezing and chest tightness develop within 5 to 10 minutes of strenuous exercise and resolve after 30 to 60 minutes of rest. Less common symptoms of cough, fatigue, difficulty keeping up with peers during training, or even stomachache may indicate exercise-induced asthma. At rest, the athlete may have a normal pulmonary exam but may show signs of allergies such as "allergic shiners" or nasal polyps. If wheezing is present at rest, the diagnosis of chronic asthma must be considered. A trial of treatment with avoidance of triggers such as cold exposure or nonsedating antihistamines may give additional supportive evidence to diagnose exercise-induced asthma. Some patients benefit from inducing a refractory period of 1 to 3 hours by performing submaximal exercise for 15 to 30 minutes before sports participation. Forming a diagnosis of exercise-induced asthma based on a clinical exam only will likely generate either over- or underdiagnosis of the problem. The diagnosis is made most accurately with spirometry performed after an exercise or environmental challenge, combined with the clinical assessment.

Complete pulmonary function tests typically conducted in a lab provide helpful data regarding an athlete's pulmonary function. Part of the complete pulmonary function test is the *spirometry,* which measures the airflow and volumes of the lungs and can be performed in an office visit or even with a portable device. The diagnosis of exercise-induced asthma is most accurately made following an appropriate exercise challenge. Whenever possible, the athlete should be tested by a sport-specific challenge in the appropriate environment (i.e., the ice rink for skaters, the pool for swimmers, etc.) and should reach an intensity of 80% to 90% of the maximal heart rate for 5 to 8 minutes. The FEV_1 (forced expiratory volume in 1 second) is the volume of air an athlete can expel in the first second of a forced expiration and is the most important parameter examined in determining airway obstruction. The spirometry measurements are typically taken before exercise, followed immediately by a postexercise challenge, and then every 5 to 10 minutes for up to 20 to 30 minutes postexercise. If the FEV_1 decreases on any reading by more than 15% from the pre-exercise values, then the diagnosis of exercise-induced asthma is confirmed. An athlete may have equivocal findings on spirometry but may show clear symptoms with exercise.

Many of the medications used to treat asthma are restricted by the World Anti-Doping Agency due to their potential effect of performance enhancement. Additional pulmonary testing may be necessary to provide appropriate documentation to allow use of these medications in the athlete. It is important to clarify the regulations that govern the athlete's participation in competition.

The goal of treatment for the athlete is proper control of symptoms and pulmonary function with exercise. As previously described, conservative treatment with avoidance of triggers, use of antihistamines, and induction of a refractory period can be considered. The first line of drug treatment involves the short-acting beta-2 agonists, such as albuterol. These medications stimulate the beta-2–type receptors in bronchial tissue, resulting in relaxation of the smooth muscle and therefore decreasing bronchoconstriction. Athletes do well with one or two puffs of the inhaler 15 to 30 minutes prior to exercise, which typically gives 2 to 4 hours of benefit. For longer events, additional doses may be required, or a long-acting beta agonist (e.g., salmeterol) may be needed for extended coverage. Since inflammation is frequently a part of asthma, inhaled anti-inflammatory medications such as cromolyn may be useful as a second-line agent for maintenance and prevention. Inhaled steroids also offer benefits to some athletes but require about 2 to 4 weeks of consistent dosing to achieve the desired effects. Inflammation may also be controlled with regular dosing of oral leukotriene inhibitors such as montelukast. In choosing a medication regimen, the substances banned by specific organizations must be considered.

Other Respiratory Disorders

Trauma

Pulmonary contusions result from a blunt injury to the chest wall that causes injury to the lung tissue with bleeding and swelling. Patients should be monitored for hypoxia, and adequate pain control is important to avoid complications of pneumonia resulting from poor inspiratory and expiratory efforts due to pain. Diagnosis is made based on the computed tomography (CT) scan, and treatment involves rest and support. Pneumothorax is the collapse of the air-filled lung tissue, resulting either from blunt trauma or spontaneously at rest or with exertion. Symptoms may include pain, cough, or shortness of breath, depending on the amount of lung tissue collapsed. Diagnosis of pneumothorax is based on the physical exam and chest X-ray. Treatment with rest, oxygen, and close monitoring is usually adequate until symptoms resolve. Athletes typically can return to activity gradually after 3 to 6 weeks depending on the symptoms and exercise tolerance. SCUBA diving is discouraged after a pneumothorax.

Hyperventilation Syndrome

Hyperventilation involves rapid and shallow breathing, often under circumstances of injury or severe stress and anxiety. Patients have trouble breathing, feel faint and confused, have numbness of the extremities, and may have muscle spasms. The athlete should be assessed for significant cardiac and pulmonary symptoms and problems but will usually improve with reassurance and slowing of the breathing rate. Rebreathing into a paper bag can be helpful in correcting the carbon dioxide level in the lungs, which is altered by the hyperventilation.

Exercise-Induced Anaphylaxis

Exercise-induced anaphylaxis is a potentially life-threatening reaction involving symptoms of a severe allergic reaction with itching, hives (urticaria), throat swelling, and spasm of the vocal cords, causing airway obstruction and a severe drop in blood pressure. It is an uncommon problem without a clear cause. Some associations that have been observed include a history of allergies; consuming shellfish, celery, or aspirin; hot/humid weather conditions; and vigorous exercise. Treatment is similar to that for other severe allergic reactions—rescue epinephrine injections and antihistamines.

Chronic Lung Disease

Chronic obstructive pulmonary disease (COPD) most often results from tobacco use or other environmental exposures, causing deteriorating pulmonary function due to obstruction of airflow. Although exercise cannot reverse the disorder, moderate levels of daily exercise have been shown to improve the symptoms of shortness of breath and the patient's ability to complete daily activities. Physician clearance is recommended prior to a patient with COPD beginning any exercise program.

Respiratory Infections

Respiratory tract infections, specifically upper respiratory infections (URIs), are one of the most common medical illnesses encountered in the care of athletes. Exercise can influence the immune system. Moderate exercise can be protective, while excessive exercise can decrease immunity. URIs are best managed through prevention. Avoiding overtraining and getting adequate rest and proper nutrition should be central to an athlete's training program. In winter sports, use of the influenza vaccine should be considered. URI symptoms run their course in 7 to 10 days, and the goal of treatment is alleviation of symptoms. Decongestants and antihistamines may be helpful but can cause sedation or affect temperature regulation. Reminders about basic hygiene, with hand washing and preventing the spread of respiratory droplets, are important in team sports. Athletes may continue to participate on a limited basis if there is no fever, proper hydration is maintained, and no symptoms of vomiting or diarrhea develop. Secondary bacterial infections such as bronchitis or pneumonia may develop and will require additional treatment.

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Retrocalcaneal Bursitis

Bursae are fluid-filled sacs located at points of contact between bony landmarks and overriding tendons. There are at least 150 bursae distributed symmetrically throughout the human body. Additional bursae can develop in areas of increased friction. Each bursa acts as a cushion that minimizes friction and allows smooth, gliding interactions between bones and tendons. The bursa is lined by a membrane that secretes synovial fluid. Synovial fluid serves to lubricate the area and facilitate motion in confined joint spaces. Without the bursae, limb movement would be painful.

Retrocalcaneal bursitis is inflammation of one or both of the bursae located just above the insertion site of the Achilles tendon to the heel bone (calcaneus). The Achilles tendon connects the calf muscles to the heel. There are potentially two bursae at this site: (1) the subcutaneous bursa is located superficial to the tendon (closer to the skin, on top of the tendon) and (2) the subtendinous bursa is located deep in the Achilles tendon (below the tendon or between the tendon and the heel bone). Normally, only the subtendinous bursa is present in the heel. However, with abnormal or repetitive pressure to the heel, a protective bursa (subcutaneous) can form between the tendon and the skin (Figure 1). People at risk of developing this bursa include runners and women who frequently wear high-heeled shoes.

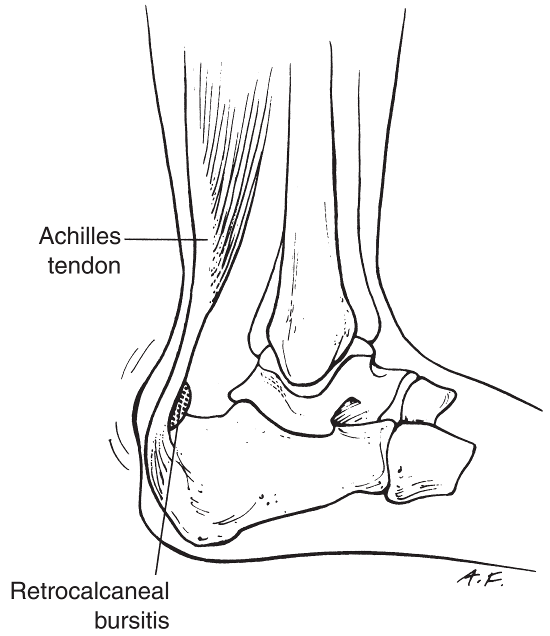

Figure 1 Retrocalcaneal Bursitis

Notes: Retrocalcaneal bursitis usually develops because of irritation of the retrocalcaneal bursa from the back of the shoe. Wearing high heels can cause this condition; hence, it is referred to as "pump bump."

Irritation of a bursa can be *acute* or *chronic*. The various etiologies underlying bursitis include trauma (inflammatory or hemorrhagic bursitis), infection, and arthritic conditions such as osteoarthritis, rheumatoid arthritis (RA), systemic lupus erythematosus (SLE), gout, and pseudogout. Overuse or repetitive microtrauma is the most common cause of retrocalcaneal bursitis.

Retrocalcaneal bursitis is diagnosed in patients of all ages and levels of activity. It is common in athletes, particularly runners. Individuals who participate in repetitive or vigorous activity or who suddenly increase the intensity of activity without proper conditioning are at increased risk for bursitis. Causes include hill-running or stair-climbing, rapidly increasing speed (such as suddenly contracting the calf muscles when sprinting), poor biomechanics, and overuse associated with tight hamstring or calf muscles. Research suggests that poor-fitting shoes with a rigid heel counter generate excessive friction and can cause bursitis. An excessively cushioned shoe may also be a culprit, due to greater stress on the Achilles tendon as the heel sinks deep into the shoe and the consequent irritation of the retrocalcaneal area.

Clinical Presentation

Patients with retrocalcaneal bursitis typically present with posterior heel pain localized directly over the bursa, increased pain with ankle motion (specifically, up-and-down movement of the foot, such as standing on tiptoes), and warmth and redness at the posterior heel. Sometimes there is a noticeable swelling, casually termed a "pump bump" due to its association with wearing high-heeled shoes (or other tight-fitting footwear). Generalized swelling can extend up to the knee. Retrocalcaneal bursitis can present with limping, and symptoms may be worst when first beginning an activity after resting. The pain decreases as the activity continues.

Types of Bursitis

Retrocalcaneal bursitis mostly occurs in the form of *inflammatory bursitis*, typically due to repetitive microtrauma. Recurring injury to the bursa triggers dilation of nearby blood vessels and increased vascular permeability, meaning that the vessels leak. That fluid, along with proteins, infiltrates the bursa. Inflammation causes synovial cells (lining the joint capsule) to multiply and thereby increases fluid production. In the acute setting, early inflammation causes the bursa to become distended. The additional bulk is perceived as foreign by the immune system, and this stimulates further inflammation.

In cases of chronic microtrauma, the wall of the bursa becomes thickened, and the contents of the bursal sac are altered. Rather than synovial fluid, the bursa is filled with granular, brown, inspissated blood and calcifications. Its gritty contents create more friction when bone and tendon move against the bursa.

Hemorrhagic bursitis is characterized by bleeding directly into the bursa. It is typically caused by violent trauma inflicted on the overlying tissues and rarely occurs at the retrocalcaneal bursae. Rapid accumulation of blood causes an acute enlargement of the bursa and accompanying pain. The increased bursal mass hinders mobility of the nearby joint.

Infectious bursitis is another possible, yet uncommon, type of retrocalcaneal bursitis. Predisposing factors include diabetes, alcoholism, steroid therapy, uremia, trauma, skin disease, and a history of noninfectious bursitis. Patients will present with extreme tenderness, warmth, and erythema at the site, and there is often evidence of injury to the overlying skin. Infection often occurs from direct introduction of bacteria through traumatic injury or by the spread of cellulitis. Acute swelling and erythema warrant aspiration of the bursa and analysis of the fluid.

Bursitis due to crystal deposition is associated with various arthritic conditions, including RA, gout, and pseudogout. On aspiration, various types of crystals may be seen based on the underlying illness. Crystal deposition and the arthritides are less common causes of bursitis.

Differential Diagnosis

Following are the conditions that need to be ruled out before arriving at a diagnosis of retrocalcaneal bursitis:

- Achilles tendinitis
- Haglund disease: impingement of the bursa between the Achilles tendon and a bony prominence on the back of the upper calcaneus (Haglund deformity); aggravated by bending the ankle upward
- Achilles tendon rupture
- Plantar fasciitis
- Stress fracture of the calcaneus
- Avulsion fracture at the calcaneus
- RA
- Gout
- SLE
- Seronegative spondyloarthropathies

Evaluation

Bursitis is typically diagnosed by physical examination. Patients often present with abrupt onset of swelling and localized tenderness over the bursa, pain with range of motion of the adjacent muscles and tendons, and warmth and redness of the overlying skin. The swelling may be discrete, as in the pump bump. It can be unilateral or bilateral. The pain may worsen with dorsiflexion (bending the ankle upward as if to walk on your heels), because this tightens the Achilles tendon and therefore puts pressure on the inflamed bursa. However, pain can also be exacerbated by plantarflexion (pointing the toes), because this stresses the Achilles tendon attachment site to the heel. Chronic bursitis may also present with disuse atrophy and weakness.

When considering retrocalcaneal bursitis, it is important to obtain a thorough medical history, including duration of symptoms, history of repetitive movement (i.e., excessive running, walking, jumping), type of footwear used and any recent changes, recent occurrence of fever, history of rheumatic conditions (e.g., RA, SLE, gout), surgical history, and recreational activities.

If the physical exam is not highly suggestive of bursitis, diagnostic testing may be done, including laboratory studies, aspiration of the bursa with fluid analysis, and radiological studies. Laboratory studies can help evaluate other possible etiologies, including gout (uric acid level), RF (rheumatoid factor), and seronegative spondyloarthropathies (human leukocyte antigen B-27 level, erythrocyte sedimentation rate, C-reactive protein). X-rays can be used to look for stress or avulsion fractures of the calcaneus as well as a Haglund deformity. Bone scans and computed tomography (CT) assist clinicians in ruling out a stress fracture. Magnetic resonance imaging (MRI) is usually reserved for cases requiring surgery. It is helpful for differentiating inflammation of the subcutaneous versus the subtendinous bursa; however, this can often be determined by physical examination.

Treatment

Treatment of bursitis should include pain control as well as rehabilitation and prevention of future injury. A seven-step plan, represented by the acronym PRICEMM (*p*rotection, relative *r*est, *i*ce, *c*ompression, *e*levation, *m*edication, and *m*odalities), has gained wide acceptance among health care providers. PRICEMM has been used as a framework for customizing a patient's rehabilitation plan.

The first step of treatment is to eliminate pressure from the affected area and to protect the joint. Movement and pressure of the inflamed area can exacerbate symptoms and impede healing. Soft-foam padding and orthopedic felt can be used to protect the affected area from increased friction or pressure. Slitting the heel counter of the shoe (cutting a "V" groove into the back of the shoe) or inserting a thick heel pad to raise the heel may help decrease friction at the retrocalcaneal bursae. For runners, it has been recommended that they change their footwear, especially if the symptom onset corresponds to wearing a new pair of shoes.

Relative rest should be prescribed to encourage patients to continue participation in exercise but to choose activities that will not further irritate the bursa. Initially, activity should be modified to avoid movements that exacerbate the pain. The overall goal should be for the patient to refrain from the triggering activity but to maintain fitness level by participating in alternative activities such as swimming. Continued physical activity accelerates the rehabilitative process. Bed rest or immobilization of the associated joint after the inflammation subsides is not advisable and should be discouraged in cases of bursitis.

Application of an ice pack will help decrease inflammation and swelling, allowing the bursa to return to its normal shape and consistency. Ice is also an effective analgesic. Direct application of ice to the skin should be done at least twice a day for 10 minutes at a time.

Compression of the affected bursa can be accomplished with an elastic bandage. While the bursa is wrapped, the extremity should be elevated above the level of the heart to decrease the amount of swelling. Elevation of the extremity for 20 to 30 minutes several times daily will facilitate removal of fluid from the affected area.

Various modalities have aided the healing of irritated and inflamed bursae. Electrical stimulation, ultrasound, and phonophoresis have been used to decrease inflammation and reduce pain. These procedures are typically done by a physical therapist. Physical therapy is often prescribed for patients experiencing weakness in an extremity or a decline in range of motion.

Medications of choice for bursitis are nonsteroidal anti-inflammatories (NSAIDs) or aspirin. The goal of using these medications is to alleviate pain and allow the patient to resume activity and participate in a rehabilitation program. NSAIDs are typically used for 4 to 6 weeks if symptoms have been present for fewer than 3 weeks at the time of diagnosis. While NSAIDs and aspirin are the preferred initial treatment, some patients will require additional medication if conservative management is not effective. Corticosteroid injections are not recommended due to the risk of injecting the Achilles tendon and the association with Achilles tendon rupture. Adverse effects on the tendon have been documented with injections of the bursae, the tendon, as well as the surrounding structures. Therefore, they are only used for the most severe, intractable cases.

Surgery is another option for treatment of bursitis; however, it is very rarely done. The main surgical candidates are patients with chronic bursitis or infectious bursitis. In chronic cases that have not improved with traditional therapy, surgery may be done to correct an anatomical abnormality, such as a bone spur. Both endoscopic as well as open surgery can be done. In cases of infection, the bursa may be opened and drained ("incision and drainage" procedure) or removed entirely.

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See also Bursitis; Foot Injuries; Lower Leg Injuries; Plantar Fasciitis and Heel Spurs

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Rhinitis, Exercise-Induced

The athlete, like everyone else, can have multiple problems related to the nose. Because of its prominent position on the face, the nose is frequently involved in trauma, leading to nasal discomfort and potential problems with congestion and leaking of fluid. Athletes also can have other nasal conditions found in the general population, such as allergic rhinitis and nasal infections, which may alter their performance.

Nose Anatomy and Function

The nose has two passageways, which contain the superior, middle, and inferior turbinates, bones that are lined by the same mucosa that covers the rest of the respiratory system. The mucosal lining contains many blood vessels that help warm and moisten the air that is inspired through the nose. The sympathetic and parasympathetic nerves reach the blood vessels and mucosa of the nose, and according to the message they carry, the blood vessels dilate (parasympathetic) or constrict (sympathetic) and the glands in the lining of the nose secrete fluid (parasympathetic). Other important cells in the mucosa of the nose include mast cells and basophils, which can release the chemicals that cause the symptoms of nasal allergies. Antibodies can also participate in the same release of chemicals from the mast cells and basophils by binding to different allergens in the environment. Several sinuses (ethmoid, sphenoid, and maxillary) and the nasolacrimal duct drain into the nose, and any swelling or distortion of these openings can lead to obstruction of this drainage system so that fluid builds up in the involved sinus. The nose also acts as a filter for polluted air by removing many different-sized particles from the air inhaled.

Physiologic Response to Exercise

During exercise, the release of epinephrine and norepinephrine increases the sympathetic tone, causing constriction of the nasal vessels. This helps to make more room in the nose and decreases airway resistance. Exercise also decreases blood flow to the nose because more blood is redistributed to the working muscles. In addition, the alar dilator muscles (nose muscles) work with each inspiration to increase the opening of the nostrils to allow more inflow of air. Higher-intensity exercise speeds up these physiologic changes. Exercise can decrease airway resistance in the nose by as much as 50%.

Rhinitis in the Athlete

Athletes can complain of fluid draining from their nose for many different reasons. Three categories of rhinitis are allergic, nonallergic, and mimics of rhinitis. Allergic rhinitis is usually seasonal, perennial, or occupational. It involves the athlete being presensitized to a particular allergen. The nasal mucosa with specific antibodies comes into contact with the allergen, resulting in the release of chemicals from the mast cells and basophils. Many different chemicals including histamine are released, causing nasal secretions and postnasal drip, itching, and sneezing. Nonallergic rhinitis includes trauma, environmental triggers that act at the level of the blood vessels to increase permeability and thus cause rhinitis, and infections. There is no specific antibody to allergen needed to trigger the mast cells to release their chemicals. Environmental triggers that can cause rhinitis include temperature or weather changes, cold exposure, particulates in the air, ozone, glues, paints, and cleaners. The common cold is the usual culprit for the new development of rhinitis, which lasts for several days. Conditions that can mimic the symptoms of rhinitis include a deviated nasal septum, nasal tumors, enlarged turbinates, and even less common mimics such as sarcoidosis and Wegener granulomatosis.

Clinical Evaluation

The nose needs to be examined through the nostril with a light source. The exam includes looking for any polyps, signs of prominent blood vessels (bluish blush), a deviated septum, and tenderness of the sinuses. Often with allergic rhinitis, the athlete will have "shiners" under the eyes related to blood congestion in the sinuses. Allergy skin testing and allergy blood tests can be done to identify which allergens the athlete should avoid and can guide the decision to desensitize the athlete to the allergen.

Treatment

Treatment depends on the severity of the symptoms and their effect on performance. Some of the medications used to treat nasal congestion can decrease athletic performance and may not be approved for use in athletes at higher levels of competition. For athletes with allergic rhinitis, antihistamines can decrease the symptoms. Unfortunately, antihistamines can also cause drowsiness; dryness of the nose, eyes, and throat; and potentially impaired sweating, making the athlete more sensitive to heat produced during exercise. Nasal steroids work for both allergic and nonallergic rhinitis because of their anti-inflammatory effects and because they decrease permeability of the nasal mucosa. Nasal cromolyn is also helpful to decrease congestion related to inhaled allergens. Intranasal anticholingerics can be effective to decrease symptoms of rhinitis. For severe symptoms, systemic corticosteroids can be used for 3 to 5 days. It is important to identify and avoid medications that are associated with rhinitis. Common drugs associated with rhinitis include oral contraceptives, aspirin, nonsteroidal anti-inflammatories, and decongestants that are used for a long period.

Complications of Rhinitis

Because mucosal swelling causes rhinitis, it can cause obstruction of the openings of the sinuses. If the obstruction occurs long enough, about 10 to 14 days, it may cause sinusitis, a bacterial infection of the sinuses. If the athlete also has concurrent asthma, the rhinitis and associated postnasal drip often increase the reactivity of the airways, making the asthma more difficult to control. Rhinitis is also associated with blockage of the eustachian tube, which drains fluid from the ear to the throat. As a result, pressure builds up in the ear and causes ear discomfort. Because the blood vessels are engorged in the nose with rhinitis, they are more prone to injury, and nosebleeds occur more frequently.

Bernadette Pendergraph

See also Air Pollution, Effects on Exercise and Sports; Allergies; Asthma

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Rhomboid Muscle Strain and Spasm

The *rhomboid* is a muscle located in the mid to upper back, connecting the thoracic spine (backbone) to the medial border of the scapula (shoulder blade). The rhomboid serves as a scapula stabilizer when one moves the arm overhead and also reaches for objects. The term *strain* describes a stretching or partial tearing of the muscle, resulting in inflammation and pain. A *spasm* is an involuntary contraction of a muscle. Depending on the mechanism of injury, the rhomboid muscle can be strained, in spasm, or, in some cases, both.

Injury Occurrence

A typical rhomboid injury may occur with either compression or overstretching of the muscle. Athletes who participate in overhead sports remain at risk for rhomboid injuries. Mechanisms such as serving a tennis ball, rowing in a crew, or throwing a baseball pitch can strain the rhomboid and result in subsequent spasm. Non–sports-related activities that may cause rhomboid strain include carrying a heavy backpack over one shoulder and poor posture when sitting at a desk.

Symptoms

After the injury occurs, patients can develop pain or muscular knots between the scapula and the thoracic spine. This pain can be constant, especially in a patient with poor posture. Otherwise, the patient may only feel symptoms if the compromising activity is repeated (e.g., serving a ball). The patient will typically not experience any radiating signs or symptoms except for those along the rhomboid muscle fibers. Frequently, patients also exhibit symptoms over the trapezius muscle (located superior and superficially to the rhomboid).

Diagnosis

The sports medicine physician typically diagnoses rhomboid spasm or strain with direct palpation of the muscle fibers as well as range-of-motion reproduction of symptoms. A patient could also perform an "air push-up" to compare scapula movement.

Treatment

Different options exist for the treatment of rhomboid spasm or strain. First, a patient can perform a home exercise program. A home exercise program includes performing a series of exercises with at least 20 repetitions twice daily to allow for both muscle strengthening and improvement in range of motion.

The first basic stretch involves a scapular range-of-motion stretch, which essentially looks like a shoulder shrug. Moving the shoulder counterclockwise or clockwise will help improve range of motion of the shoulder. Shrugging the shoulder and holding the shoulders back together for 5 to 10 seconds can also stretch the muscle.

The second stretch involves a pectoralis muscle wall stretch. The patient should go to a corner of the room, placing the hands at about 90° abduction (shoulder height), and perform a wall "push-up." This stretch allows the patient to strengthen and lengthen the muscle. The patient can hold down for 5 to 10 seconds again to maximize lengthening of the muscle. A similar stretch may be performed using elastic resistance bands and tubing. Placing the hands at the same angle, the patient can retract with the band offering resistance. A fourth stretch includes placing the hand on the affected side against a door frame and tilting the body back. This stretch again improves shoulder stabilization and proprioception.

Finally, patients can clasp their hands together and reach directly in front of them. This technique is similar to progressive resistance training, which helps stabilize the shoulder. The patient should apply ice for approximately 20 minutes after performing the home exercise program to help decrease any reflex inflammation.

In addition to the home exercise program, the patient may take nonsteroidal anti-inflammatories (NSAIDs), such as ibuprofen or naproxen, for 10 days to increase the anti-inflammatory effect. After this time, the medicine simply serves as a pain reliever.

Massage treatment can be helpful to decrease spasm. Athletes may place a tennis ball on the floor under their rhomboid muscle and roll over the ball in an up-and-down fashion to release the rhomboid spasm.

If the spasm is unresponsive to the home exercise program and ice application, trigger point injections can be given. Trigger point injections consist of a 25-gauge (or lower), 1.5-inch (3.81-centimeter) needle with an anesthetic (lidocaine 1%). Evidence-based medicine shows that a slight triggering (needling) of the muscle spasm with the syringe can decrease the involuntary spasm directly. Lidocaine serves as a pain reliever for the needling. Following the trigger point injection, osteopathic manipulative treatment may be performed. A technique called myofascial release involves adding pressure with the thumb over the muscle spasm to decrease the contraction. The trigger point injection decreases the muscle spasm.

If these techniques are not effective, then the patient may attend formal physical therapy twice weekly for 6 weeks. Treatments may be augmented from the home exercise program to focus on the specific area of the rhomboid that was unresponsive to prior treatments.

Return to Sports

The athlete should have no residual range-of-motion deficiency or weakness prior to return to sports. Early return to play without appropriate treatment may disrupt the athlete's typical playing form or style. A tennis player or volleyball player may need an altered serve to maintain strength. A crew member may not exhibit his or her typical form on a rowing stroke. This adaptation could lead to further back pain as a result of muscular compensation.

Prevention

Similar to the lumbar core stabilization program, scapula stabilization is essential for performing activities of daily living as well as sports-related activities. Any patient with a history of rhomboid strain and spasm should consider a daily home exercise program to maintain scapula stabilization.

Douglas Comeau

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Rib Fracture and Contusions

Rib injuries are a common cause of chest wall pain in the athlete. It is vital to differentiate pain from an injured rib from other causes of discomfort such as referred pain from the spine, a systemic process like arthritis, or more life-threatening symptoms like a pneumothorax.

Typically, rib injuries occur in the athlete due to overuse or trauma. These injuries may be classified as either contusions or fractures. *Contusions* are bruises to the soft tissues and associated bony structures. Stress fractures tend to occur when there is repetitive stress placed on the rib by mechanisms such as muscle contraction(s). Fractures can occur with direct or indirect injury. Indirect injuries occur with a spontaneous and powerful contraction of a muscle that leads to breakage of the bone. Avulsion fractures occur in the lower ribs due to contraction of the external oblique muscles. This injury has been described in a javelin thrower. Direct injuries occur when the ribs sustain a blunt force. Athletes most at risk for rib stress injuries are those who use their shoulder and thoracic girdle muscles repetitively, such as baseball pitchers, rowers, and gymnasts, while those at risk for direct trauma typically play or are involved in contact sports.

Understanding the anatomy of the chest wall will help the practitioner and athlete prevent and diagnose rib injuries. The chest wall houses the heart, lungs, and major vessels. There are 12 ribs in the chest wall. The first 7 are considered "true" ribs as they attach to the sternum via costochondral cartilage. The 8th through 10th ribs are referred to as "false" ribs since they attach not to the sternum but to adjacent ribs via costochondral cartilage. The term *floating ribs* refers to the 11th and 12th ribs, which have no attachment anteriorly. The ribs attach posteriorly to the spine. Muscles involved in throwing, rowing, and weight lifting attach to the ribs at various points. The practitioner must always be on the alert for associated injury given the potential for injury to the underlying lung, cardiac, and vasculature structures. For example, fractures of the lower ribs can lead to injury to structures within the lung and the abdomen.

Athletes with rib fractures will present with various symptoms depending on their fracture location and type. Athletes may present with localized pain directly over the involved rib. There may be associated muscle spasm, bruising, and hesitancy to take a deep breath in.

The ribs most susceptible to blunt trauma are the fourth through the ninth ribs. Athletes can sustain more than one rib fracture. These athletes typically receive significant blunt trauma to the chest wall. They may have difficulty taking a deep breath due to pain, splinting of their chest wall, and are at risk for a *pneumothorax* (air around the lungs) or *hemothorax* (blood around the lungs). These athletes should be evaluated in an emergency department. Not all acute rib fractures can be diagnosed on x-ray, especially if they are located on the front or side of the chest and involve the first five ribs. Plain films are useful for diagnosing other injury such as pneumothorax. It has been recommended that individuals require X-ray who have suspected fractures of either Ribs 1 or 2, or 9 through 12; multiple rib fractures; are elderly; or have the potential for pathologic fractures.

Treatment of fourth through ninth rib fracture depends on the patient's level of comfort and ruling out other associated underlying life-threatening injuries. This can be done with oral pain medication. Athletes are encouraged to take deep breaths during the recovery process to avoid collapse of the small airways. Binders are no longer recommended because they result in decreased ventilation.

The first and second ribs require a lot more force to fracture than the rest of the ribs. Acute traumatic fractures can be indicators of more significant injury involving the great vessels or other organs within the chest wall. Fractures to the first rib have been documented in overhead athletes, that is, baseball, basketball, weight lifting, and tennis. The muscles involved in throwing, such as the scalene muscles, cause fatigue to the bone with repetitive use. Stress injuries can occur with rapid changes in training like increased time or intensity. Acute fractures can also occur with motions such as swinging a bat without any direct contact. Athletes will complain of pain in the back of the shoulder. This can be either subacute in cases of stress injury or acute with an associated "pop" with indirect or direct trauma. The clinician may perform a chest X-ray to evaluate the fracture. However, triple-phase bone scan is the imaging modality of choice. Other options do include computed tomography (CT) scan or magnetic resonance imaging (MRI).

Treatment of first and second rib fractures involves adequate analgesia and a sling to the involved shoulder girdle to prevent provocative maneuvers. Healing can take up to 8 weeks. It is not uncommon for these to have a delayed or fibrous union. Surgery is recommended for a persistently painful nonunion.

Stress fractures to ribs beyond the first and second occur when there is an increased load to the bone. The bone fatigues and develops microfractures that then lead to stress fracture. This occurs via repetitive muscle contraction with an increase in training (time, volume, intensity) or a change in technique. Rowers and golfers are at increased risk due to their use of muscles such as the serratus anterior. Rowers may need to have equipment changes such as changing the shape of the oar to prevent further occurrences. Athletes will complain of pain over their back. Given the elastic nature of the chest wall, taking a deep breath can aggravate the symptoms. Treatment of these stress injuries is similar to stress injuries to the first and second ribs: modified activity, analgesia, and prevention.

The examiner should perform a thorough physical exam including a heart, lung, and abdominal exam in any athlete at risk for a potential rib injury. There may be point tenderness on palpation (although palpation may be difficult if the fracture occurs under the scapula). Chest X-ray may be diagnostic; however, triple-phase bone scan is again the modality that will confirm the diagnosis. Treatment involves allowing time for the bone to heal. This usually takes 4 to 6 weeks of relative rest with a gradual progression toward competition by 8 weeks. It is important for athletes to have someone evaluate their technique, strength, training schedule, and flexibility to avoid further injury.

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See also Abdominal Injuries; Chest and Chest Wall Injuries; Protective Equipment in Sports

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Rib Stress Fracture

Stress fractures occur when a bone fails to withstand repetitive stress. Activities such as running or jumping generate forces of multiple times a person's body weight and place weight-bearing bones under a lot of pressure. Thus, stress fractures usually occur in bones that are weight bearing. However, stress fractures can also occur in bones that are not weight bearing, such as the ribs. Rib stress fractures are caused by multiple mechanisms and can occur in athletes who participate in golf, rowing, canoeing, swimming, running, baseball (especially pitchers), javelin throwing, weight lifting, tennis, basketball, surfing, and squash. Rib stress fractures can also be caused by strenuous coughing, backpacking, or pregnancy. Rib stress fractures are seen most often in rowers. There has been an increase in the incidence of rib stress fractures among rowers since the arrival of new, more technologically advanced equipment. Rib stress fractures in rowers account for much time lost from training and competition. Women are more likely than men to suffer a rib stress fracture. No one knows definitively why women are more susceptible than men; however, in general, women's bones have less bone mineral density than men's and thus may be more susceptible to stress fractures.

Anatomy

The ribs are 12 paired bones in the chest that make up the rib cage. The first 10 ribs attach to the sternum (breastbone) and the spine. The ribs are connected to the sternum by the costal cartilage. Ribs 11 and 12 are floating ribs and do not connect to the sternum at all. The rib cage protects the heart, lungs, and other vital organs. The ribs, together with the diaphragm, enable inspiration and expiration (breathing). Most often, rib fractures occur centrally on the first rib, laterally on Ribs 4 through 9, and posteriorly on the upper ribs. There are several muscles that attach to the rib cage. One of these, the serratus anterior, is the muscle most often implicated as a cause of stress fractures. The serratus anterior attaches on the lateral part of the first eight ribs and wraps around the side of the body to attach posteriorly to the scapula.

Causes

Stress fractures occur when a bone fails to withstand the stress placed on it. When the stress or injury occurs at a rate faster than can be repaired by the bone, a fracture develops. The repetitive nature of many sports, such as rowing, produces a pattern of repetitive strain that is produced on a frequent basis. Repetitive muscle forces acting on the ribs are a possible cause of the imbalance that can lead to a stress fracture.

There is no consensus as to the exact mechanism that leads to stress fractures in rowers. Various causes include stress from the serratus anterior, pull from the abdominal muscles, or muscle fatigue, which weakens the protection the muscles provide to the ribs, thus making them more susceptible to injury. New equipment and increased use of indoor rowing ergometers seem to be contributing factors to the problem. Modern oar technology allows for more loading of the oar than the traditional wooden oars and is suspected to contribute to the increasing incidence of rib stress fractures among rowers.

A golfer can develop a stress fracture if he or she repeatedly strikes the ground by accident while swinging. This commonly occurs with novice golfers. The collision of the club with the ground causes traction of the serratus anterior muscle, which over time causes damage to the rib and leads to a stress fracture. Stress fractures also occur in golfers who dramatically increase the number of swings they take per week. Injury from the increased load is most likely due to repetitive muscle use.

The first rib is susceptible to stress fracture in people who do a lot of work overhead, such as throwers, weight lifters, or even wallpaper hangers. It is believed that the first rib is susceptible to injury because it has two grooves on the upper surface, on which the subclavian vein and artery rest. The bone is thin in these areas. In addition, the first rib must endure stress from the downward force of the intercostal and serratus anterior muscles as well as the vertical forces of the scalene (neck) muscles. The combination of muscle traction and the thin area of the bone makes those who spend a lot of time throwing or working with their arms over their head susceptible to first rib fractures.

Symptoms

Rib stress fractures can present in a variety of ways. The symptoms will vary depending on the rib that is injured and the location of the injury. Pain will be felt at the point of injury but can also be felt along the distribution of the nerve that accompanies the rib (intercostal nerve). An irritation of the pleura (lining of the lung) can also occur. The pain initially starts with activity only but eventually becomes present with almost all motions (including breathing) as the injury progresses. The pain experienced will intensify when breathing deeply, coughing, laughing, or sneezing.

Most rowing stress fractures occur in Ribs 4 through 8. Sweep rowers (those with a single oar) most often have fractures anterior and lateral on the rib as opposed to posterior. There is no connection between the rower's side of the boat (port or starboard) and the side of the body where the stress fracture is located. Scullers (rowers with two oars) get anterior stress fractures just as often as posterior fractures.

Golfers with stress fractures will have pain in the upper back. Usually, the pain is located on the side of the nondominant hand. Many do not seek treatment immediately because they think they have a muscle strain. First rib stress fractures can produce a dull, aching pain in the shoulder or collarbone. The pain will follow a similar pattern as mentioned above but will especially occur with overhead activities.

Diagnosis

A history and physical exam are the first steps when diagnosing a stress fracture. Tenderness to palpation will be present over the area of the stress fracture. To confirm the diagnosis, radiographs are needed. Plain radiographs will sometimes miss the diagnosis; however, if healing is already taking place, a callus will be visible. Because plain films often do not reveal the fracture, the best test to detect the stress fracture is skeletal scintigraphy (bone scan). On these films, the stress fracture will light up as a "hot spot" over the rib where the injury has occurred. Computed tomography (CT) scans are not ideal for making the initial diagnosis but are helpful to monitor healing and may be ordered 4 to 6 weeks after the diagnosis to aid in deciding when an athlete can be cleared to return to athletic activity.

Treatment

Stress fractures are treated nonoperatively. The initial treatment for rib stress fractures involves rest for 4 to 6 weeks from activities. The athlete must take particular care to avoid movements that provoke pain. Return to physical activity must begin gradually and should start with basic activities before slowly reintroducing sport-specific activities. The technique and the biomechanical form of the athlete should be evaluated to identify the problem areas that might have led to the injury. Errors in biomechanical form should be corrected before allowing the athlete to return to play. Pain can be controlled with pain medication. After 4 to 6 weeks, higher-level athletes might undergo a CT scan to confirm bony healing. If there is no evidence of bony healing on CT images, the athlete would perhaps benefit from a longer period of rest. In some cases, healing will never occur, resulting in a nonunion. However, athletes have been able to eventually return to play free of pain despite not achieving bony healing.

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Rib Tip Syndrome

Rib tip syndrome is a condition that is often misdiagnosed or undiagnosed and can subsequently lead to months or years of unresolved abdominal and/or thoracic pain.

This syndrome was first described in 1919 but was not officially named until 1922. The syndrome, variously called slipping rib syndrome, clicking rib, displaced ribs, interchondral subluxation, nerve nipping, painful rib syndrome, rib tip syndrome, slipping rib cartilage syndrome, traumatic intercostals neuritis, and 12th rib syndrome, is associated with hypermobility of the anterior end of a costal cartilage.

Anatomy

The human rib cage is part of the human skeleton within the thoracic area. A typical human rib cage consists of 24 ribs, 12 on each side of the thoracic cavity; the sternum; and the 12 thoracic vertebrae.

In the front, the upper seven ribs are attached to the sternum by means of the costal cartilages. Due to their elasticity, they allow movement when inhaling and exhaling. The 8th, 9th, and 10th ribs join with the costal cartilages of the ribs above. The 11th and 12th ribs are known as floating ribs as they do not have any anterior connection.

Causes

The cause of the painful rib syndrome is not known. Although it is often related to minor trauma, constrained posture, or previous abdominal surgery, the etiology of rib tip syndrome remains unclear because many patients do not recall any such event.

According to the original mechanical description, Ribs 8 through 10 (false ribs), which are not connected to the sternum but are connected to each other via a cartilaginous cap or fibrous band, tend to be the most mobile and susceptible to trauma.

The weakness of the rib-sternum (sternocostal), rib-cartilage (costochondral), and/or rib-vertebral (costovertebral/costotransverse) ligaments leads to rib hypermobility. This allows a rib to slip behind the rib above it, and the slippage or movement can lead to irritation of the intercostal nerve, strain of the intercostal muscles, sprain of the lower costal cartilage, or general inflammation in the affected area.

Symptoms

This disorder may account for 1% to 5% of all patient visits in a general medical practice. Cases have been reported in children as young as 7 years as well as individuals in their mid-80s, with the syndrome affecting females slightly more than males. Among athletes, wrestlers seem to be the most commonly affected, but it can be a problem in just about any sport.

The painful rib syndrome consists of three features: (1) pain in the lower chest or upper abdomen, (2) a tender spot on the costal margin, and (3) reproduction of the pain on pressing the tender spot.

The main symptom is upper abdominal pain, equally common on either side and occasionally bilateral. The pain is precipitated by movement and certain postures (e.g., bending, coughing, deep breathing, lifting, reaching, rising from a chair, stretching, and turning in bed) and is invariably reproduced by pressure at one or more points on the costal margin.

The rib end may also subluxate across the medial attachment site or another rib border. This will lead to a popping, clicking, snapping, grating, or "giving way"' sensation, associated with a sudden, often severe, exacerbation of pain. The pain may then fade away over the course of minutes to 1 to 2 hours or may persist as a lesser, dull pain punctuated by severe periodic exacerbations induced by subluxations.

Diagnosis

Rib tip syndrome has a large variety of differential diagnoses, such as cholecystitis, esophagitis, gastric ulcer, hepatosplenic abnormalities, stress fracture, inflammation of the chondral cartilage, and pleuritic chest pain. The definitive diagnosis is usually made based on the history and physical examination.

As part of the diagnosis, the clinician needs to look for an association between certain movements or postures and pain intensity. Determine if the patient has experienced recent trauma (although it may not always be present), and reproduce the symptoms (e.g., pain, clicking) with the hooking maneuver. A positive hooking maneuver is a reproduction of the pain event induced by the examiner curving his or her fingers under the costal margin and gently pulling superiorly and anteriorly, inducing subluxation of the offending cartilage.

Often, one may also be able to identify the affected rib by pressing on the ribs in the midaxillary line. Movement of the disrupted rib end can reproduce the symptomatic pain of the slipping rib. The intercostal nerve block or rib block is recommended to confirm the diagnosis, as demonstrated by the abatement of symptoms.

Radiologic imaging (X-ray, sonography, bone scan, computed tomography [CT], or magnetic resonance imaging [MRI]) is generally not useful in the diagnosis of slipping rib syndrome but may be of value in ruling out other conditions in the differential diagnosis.

Treatment

There are three modes of treatment for slipping rib syndrome: (1) simple reassurance, (2) intercostal nerve block or rib block, and (3) surgical repair or resection. For an athlete wishing to compete within a few days of treatment, the intercostal nerve block may be very useful.

Treatment should initially be conservative, but if the symptoms persist or recur, surgical excision is indicated. Surgery may be necessary more often than not to provide definitive treatment.

Nonsurgical Treatment

Once the diagnosis of slipping rib syndrome has been made, the patient should be educated concerning the condition. Simple reassurance and avoidance of movements or postures that exacerbate symptoms may be sufficient to elicit a successful outcome. Certain strength training maneuvers that involve the trunk/core might need to be avoided by the athlete for a period of time.

Patients can also consider other conservative measures such as icing, stretching, ultrasound treatments, hot packs, nonsteroidal anti-inflammatory medications, physical therapy (e.g., soft tissue mobilization, myofascial release, anterior-posterior mobilization from T9 through L2), stretching, and strengthening activities. Osteopathic manipulation can also be used to restore maximal painfree movement of the rib cage through the appropriate use of myofascial release and functional techniques.

Before recommending surgical excision of the rib tip, temporary relief of pain can be obtained from local injection of steroid (e.g., methylprednisolone acetate) and local anesthetic (e.g., 1% lidocaine) into the painful sites.

Surgery

Surgical treatment is typically reserved for those in whom conservative/nonsurgical management has failed. The procedure can usually be done in an outpatient setting, but in some cases, the patients may need to be kept in the hospital overnight for observation.

The point of maximal tenderness is localized preoperatively, and the resection is centered at that point. A subperiosteal/subperichondrial resection of the involved rib and cartilage is then performed. Care should be taken to avoid entering the pleural space. If this were to occur, simple aspiration and closure of the pleura is performed, avoiding placement of a tube thoracostomy.

Surgical excision of the subluxating cartilaginous rib tip is the definitive therapy. Patients with a long history of pain can obtain relief by cartilage excision. This involves little morbidity and can frequently be performed under local anesthesia.

After Surgery

The patient is restricted from activity for 6 weeks following surgery. After this time, light rehabilitation exercises can begin, and the patient is then progressed through the rehabilitation program as tolerated. Return to contact sports is recommended once full-intensity noncontact activities are tolerated. In some cases, a "flak jacket"–type rib protector may be helpful for return to play in the first few weeks to months.

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Risk Factors for Sports Injuries

Millions of people participate in sports each year. In the United States alone, there are an estimated 30 million children who participate in organized sports and approximately 150 million adults who participate in non–work-related physical activity. With this level of participation, a significant number of sports-related injuries are bound to occur. These injuries are a significant problem and cost to society. Identifying the common risk factors and mechanisms of injury is a necessary condition for strategizing and creating preventive programs.

Types of Risk Factors

Risk factors are typically classified as *intrinsic* or *extrinsic*. An *intrinsic* risk factor is an *internal* factor that can predispose one to injury. Intrinsic risk factors include age, anatomy, fitness level, gender, previous injury, and psychological factors. For example, according to injury data, boys between the ages of 10 and 14 are at higher risk for a sports-related injury.

An *extrinsic* risk factor is an *external* factor that can influence a person's susceptibility to injury. Extrinsic risk factors include clothing, coaching, equipment, hours of exposure, playing surface, technique, training, and the weather. For example, frostbite is the freezing of the skin that results from exposure to very cold temperature. Air temperature, wind speed, and moisture all affect the rate at which the body loses heat. Playing on a muddy or uneven surface would increase the likelihood of ankle or knee injury.

Risk factors can also be categorized as *modifiable* and *nonmodifiable*. *Modifiable* risk factors refer to those that can be altered by preventive strategies to reduce injury. *Nonmodifiable* risk factors, such as age and gender, cannot be altered. While nonmodifiable risk factors are important to consider, more emphasis is often placed on modifiable risk factors, since they can be altered to reduce injury rates.

Sports injuries result from a complex interaction of the above intrinsic and extrinsic risk factors, coupled with an inciting or triggering event. For example, an intrinsic risk factor can predispose an athlete to injury, but injury will not occur by itself. The athlete will have to be exposed to an extrinsic risk factor, followed by an inciting event that leads to injury. To clarify further, an example would be a female adolescent with weak hamstrings and hip instability (intrinsic risk) who is playing soccer on an uneven surface (extrinsic risk) and gets pushed (inciting event), leading to rupture of her anterior cruciate ligament.

The importance of gaining a better understanding of the risk factors for sports injuries is that if we can identify these risk factors and modify or develop preventive strategies, then we can influence the health of athletes in a positive manner. Research continues to look at the complex interaction between risk factors that leads to injury and is focused on the development of risk reduction techniques. The determination of the cause of sports injuries needs to account for the varied nature of these injuries by including as many risk factors as possible. Risk factor studies need to be carefully designed. Ideally, this design would include a group of athletes with similar demographics and risks who can be followed over time. The group size would also need to be large enough to give it the power for statistical significance.

The other important condition to help clinicians, and ultimately the population at large, to better understand risk factors for sports injuries is for the individuals conducting the research to convey the data and statistics in meaningful terms. For example, the mean playing time before an injury occurs is x, or the chances of injury in a season are y. The uncertainty in the estimate of a risk factor statistic provided by a study also needs to be clearly conveyed.

Studies published to date on the risk factors for sports injuries often have methodological limitations and inadequate sample sizes, and because of this, as well as the issues outlined above, it is still difficult to definitively establish the cause-and-effect relationship of many perceived risk factors and the subsequent sports injuries. However, published research data have suggested specific risk factors; the following are some examples.

Baseball

Ongoing efforts to reduce baseball injuries have led to the introduction of protective equipment, softer baseballs, and better coaching and pitching programs to reduce overuse injuries. Safety balls have reduced the risk of ball-related injuries, with reduced-impact balls being the most effective. However, no safety ball can remove all risk of injury. Better coaching techniques, appropriate field conditions, and proper equipment may further reduce injury potential. For example, teaching young batters to turn away from the oncoming ball, along with not using the on-deck circle, may help prevent injury. Correct sliding technique and breakaway bases also decrease injury. Also, monitoring of pitch counts has been shown to reduce the incidence of overuse injuries related to the elbow and shoulder.

Football

Helmet modifications have been successful in reducing facial and dental trauma. There is ongoing research looking at helmet modifications and the risk of concussion. Improper use or fit of helmets increases injury risk. A recently designed shoulder pad that incorporates a cooling system has been shown to decrease core body temperature, thus potentially decreasing the risk of heat-related illness. Improvements in coaching technique and rule changes have reduced the risk of cervical spinal injuries in football. Coaches have taught players not to use the top of their helmets to tackle, block, or strike opponents and that contact should always be made with the head up and never with the top of the head or helmet. The "spearing rule," which penalizes players for lowering their head and making contact with the top or crown of the helmet, was implemented at the college and high school levels in 1976. This rule change caused a dramatic reduction in the number of quadriplegic injuries.

Soccer

Shin guards decrease the average force transmitted to the leg during trauma and decrease the risk for tibia fracture. Like other types of protective gear, shin guards must be used properly and worn during the game or practice to reduce the risk of injuries. A change in the anchoring of soccer goalposts has decreased the risk of head trauma: Padding systems on stationary goalposts in soccer have a similar effect to breakaway bases in softball and baseball—a reduction in injuries without altering the enjoyment or flow of the game, with the benefit of a potential reduction in associated health care costs.

Ice Hockey

In hockey, catastrophic head, neck, and eye traumas have decreased with the use of helmets, full face masks, and mouth guards, and the incidence of traumatic blindness has significantly lessened. Studies have concluded that full face masks offer the best protection against facial, eye, and head injuries without an increased risk of neck, concussion, or spinal cord injuries. Mouth guards decrease the risk of dental and oral-facial trauma. Body checking accounts for many injuries in young athletes, and many organizations have imposed restrictions on this for youths below certain ages.

Overuse Injuries

The type, frequency, intensity, and duration of training play a major role in the etiology of overuse injuries. The etiology of overuse running injuries, for example, includes extrinsic factors (training errors, use of old shoes, running surface irregularities) and intrinsic factors (poor flexibility, malalignment). The risk of injury is higher in an individual with poor alignment and flexibility who is wearing old shoes and running more than 40 miles (mi)/week on rough, hard terrain than in an individual with good flexibility, normal alignment, and new shoes who is running fewer than 30 mi/week on flat, soft terrain.

Playing Technique

Research has focused on the playing technique. One area of particular interest is the high rate of noncontact anterior cruciate ligament (ACL) injuries in young female athletes engaged in contact or cutting sports such as soccer and basketball. Prospective studies have shown a significant decrease in ACL injuries in female athletes engaged in soccer and basketball who are taught a structured technique of cutting and turning before engaging in their sports. Their rate of injury was significantly less compared with controls.

Prevention of Sports Injuries

Risk factor determination for sports injuries is paramount to designing prevention programs. Before preventive measures can be implemented effectively, it is critical to determine what types of injuries occur, who sustains them, and why they occur. This continues to be challenging to definitively determine. Injury surveillance programs currently in place and those being developed will help facilitate this. However, it is critical to refine the methods of data collection and to attempt to minimize the fragmentation of reporting. Through effective programs, sports injury reduction will be achievable.

Tod Sweeney

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Rotator Cuff Tears, Partial

The *rotator cuff* is made up of four muscles whose tendons merge to be inserted on the humerus. The subscapularis is anterior, and the suprapinatus superior and the infraspinatus with teres minor are posterior. The function of the rotator cuff is to keep the humeral head centered on the glenoid of the scapula, thus optimizing the effect of the other muscles around the shoulder. The rotator cuff can also initiate movement by itself.

This group of tendons can frequently tear. A tear that does not involve the full thickness of one or more tendons is called a *partial tear*.

Types

There are three types of partial tears: (1) bursal-side tear (BT), confined to the bursal (outer) surface of the tendon; (2) intratendinous tear (IT), found within the tendon; and (3) joint-side tear (JT), present on the side of the tendon adjacent to the joint (inner side).

Incidence

The true incidence of partial tears is not known. Most data have been obtained from cadaver and imaging studies. Yamanaka and Fukuda reported an incidence of supraspinatus partial-thickness and full-thickness tears of 13% and 7%, respectively, in a group of 249 cadaveric specimens in 1987. Partial-thickness tears were further grouped as bursal sided (2.4%), intratendinous (7.2%), and articular sided (3.6%). However, several authors have noted that, clinically, articular-sided tears are two to three times more common than bursal-sided tears. In fact, in a population of young athletes, articular-sided tears constituted 91% of all partial-thickness tears.

Partial tears of the suprapinatus are the most common, but tears can also occur in the infraspinatus and subscapularis.

Pathology

Causative factors can be broadly categorized as either intrinsic or extrinsic to the rotator cuff tendons.

Intrinsic causes may be subclassified into metabolic and vascular changes that lead to degenerative tearing or intratendinous lesions developing from shear stress. A zone of relative poor blood supply is seen on the articular surface of the rotator cuff 1 to 2 centimeters from its insertion on the humerus. This area is particularly at risk for tear.

Extrinsic causes include subacromial impingement (trapping of the tendon by the acromial spur), shoulder instability (typically anterior), internal impingement (trapping of the tendon by the humeral head), a single acute traumatic injury, or repetitive microtrauma.

Often, more than one of these factors (either intrinsic or extrinsic) is responsible for the development of a partial-thickness tear. The articular surface of the rotator cuff has an ultimate stress to failure that is approximately half that of the bursal surface, with thinner and less uniformly arranged collagen bundles. It is believed that articular tears are due to intrinsic pathologic changes of the rotator cuff, whereas bursal-side tears are associated with subacromial impingement on an underlying, milder pathologic change of the rotator cuff.

Diagnosis

Pain, especially at night, is the most irritating symptom. Partial tears can be more painful than full-thickness tears.

The results of impingement tests, such as the Neer and Hawkins tests, with or without subacromial local anesthetic injection, are often positive in the presence of partial-thickness rotator cuff tears, although occasionally these test results are negative, especially in the high-level, well-conditioned athlete.

> *Neer test:* The Neer impingement sign is elicited when the patient's rotator cuff tendons are pinched under the coracoacromial arch. The test is performed by placing the arm in forced flexion with the arm fully pronated (thumb pointing to the floor). The scapula should be stabilized during the maneuver to prevent scapulothoracic motion. Pain with this maneuver is a sign of subacromial impingement.
>
> *Hawkins test:* The Hawkins test is another commonly performed assessment of impingement. It is performed by elevating the patient's arm forward to 90° (with the elbow bent) while internally rotating the shoulder forcibly. Pain with this maneuver suggests subacromial impingement or rotator cuff tendinitis.

Loss of supraspinatus muscle strength with complete or near-complete resolution of pain after a subacromial injection of local anesthetic suggests the presence of a full-thickness rotator cuff tear, whereas maintenance of strength with or without pain on supraspinatus testing suggests either rotator cuff inflammation or a partial-thickness tear.

Evaluating Rotator Cuff Strength

The following tests are used to evaluate the strength of the rotator cuff muscles:

> *Supraspinatus test (empty-can test):* Abduct the shoulders to 90° in forward flexion with the thumbs pointing downward. The patient then attempts to elevate the arms against the examiner's resistance.
>
> *Infraspinatus test:* With the arms at the sides, the patient flexes both elbows to 90° while the examiner provides resistance against external rotation.
>
> *Subscapularis test (lift-off test):* The patient rests the dorsum of the hand on the back, in the lumbar area. Inability to move the hand off the back by further internal rotation of the arm suggests injury to the subscapularis muscle.

The examination is completed by assessing the shoulder for associated pathology such as instability, biceps lesions, and capsular contractures (loss of internal rotation), which can cause internal impingement.

On plain X-ray, a subchondral cyst in the greater tuberosity may also be seen in the presence of rotator cuff pathologic abnormalities.

Ultrasound is a valuable and cost-effective procedure, although it is very operator dependent. It can detect partial tears with an accuracy of over 90%.

Magnetic resonance imaging (MRI), with injection of a contrast medium into the shoulder (arthrography), is the most accurate method of imaging. A significant advantage of MRI, and more specifically magnetic resonance arthrography, is the ability to diagnose concomitant abnormalities, which is critical to providing optimal treatment. Placement of the arm in a position of *ab*duction and *e*xternal *r*otation (ABER view) has also been a useful adjunct to routine imaging to identify not only articular-surface tears but also biceps lesions.

Diagnostic arthroscopy allows both diagnosis and treatment of partial tears.

Treatment

The treatment depends on the associated conditions. If an isolated problem is diagnosed clinically and radiologically, then initially nonoperative treatment can be attempted. Alternatively, patients may undergo operative treatment.

Nonoperative Treatment

Patients with partial-thickness tears due to suspected external acromial impingement are treated similarly to those with rotator cuff tendinopathy and subacromial bursitis. Activity modification with avoidance of overhead or pain-provoking activities is recommended, along with a short course of a nonsteroidal anti-inflammatory medication to reduce the associated pain and inflammation of the condition. A dedicated physical therapy program is recommended, with specific attention directed toward reestablishing and/or maintaining normal shoulder kinematics with stretching of the contracted capsular structures.

Anterior capsular tightness is addressed by stretching in external rotation with the arm at the side to avoid placing the shoulder in a zone of impingement (60°–120° of abduction). Posterior capsular contractures are eliminated by stretching with the arm in adduction and internal rotation and horizontal, cross-body adduction. Thermal modalities (e.g., moist heat, ultrasound) can be used to facilitate the reduction of pain and improve motion, although data to support their use are limited. Subacromial or intraarticular corticosteroid injections can also be used judiciously, depending on the location of the tear, for those patients with persistent symptoms unresponsive to other means of pain reduction. No more than two or three injections are recommended because of their potentially deleterious effect on the rotator cuff tissue, especially in younger athletes. As pain decreases and shoulder motion improves, attention is focused on strengthening the rotator cuff and periscapular musculature. Strengthening of the shoulder girdle musculature is recommended to restore normal scapulothoracic mechanics to stabilize the platform on which the glenohumeral joint functions. Left unaddressed, scapulothoracic dyskinesia increases the likelihood of extrinsic acromial impingement on the rotator cuff.

Throwing athletes with coexistent anterior shoulder instability, internal impingement, or both are treated similarly, with pain reduction through the use of anti-inflammatory medications and strengthening of the muscles of the rotator cuff and shoulder girdle complex. Particular emphasis should be placed on stretching the contracted posterior capsular tissues, which have been shown to result in the loss of internal rotation.

Eccentric and plyometric strengthening of the rotator cuff should be included in the rehabilitation program to mimic the deceleration and follow-through phase of the throwing motion. Trunk and lower extremity strengthening should also be emphasized during this time, as significant throwing strength is generated from these areas. Attention to core strengthening reduces the degree of effort that the shoulder and arm must exert to produce power during throwing. Restoration of correct throwing mechanics is followed by a progressive throwing program specific to the demands of the patient's sport.

Operative Treatment

Operative treatment is still controversial, and clear guidelines are not available. The options include

- debridement,
- rotator cuff repair, and
- debridement/repair with or without subacromial decompression (removal of the acromial spur).

Bursal tears generally do poorly with debridement alone, and repair is preferred, especially given its better blood supply.

Indications for repair of articular-sided tears are controversial, but generally, repair is indicated if the tear involves greater than 50% of the tendon.

Intratendonous tears are treated by debridement of the nonviable tissue and repair of the defect with sutures.

Outcomes of Treatment

With conservative treatment, 80% of tears will improve. The best form of treatment for the overhead athlete is a matter of debate, with good results reported with both debridement and repair. Treatment for the baseball pitcher is problematic, with poor results reported for debridement alone and a significant risk of failure to return to the previous level with repair.

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Rotator Cuff Tendinopathy

Rotator cuff tendinopathy is a common cause of shoulder pain and results in a substantial number of doctor visits annually. Shoulder pain can have many sources, but rotator cuff disorders are highly prevalent in the athletic population. In particular, sports that require overhead activity put athletes at higher risk. These sports include swimming, tennis, baseball, golf, volleyball, and gymnastics.

Traditionally, the term *tendinitis* has been used to describe a painful tendon injury. However, as clinicians and researchers have begun to learn more about what causes dysfunction and pain in tendons, the term *tendinitis* is less widely used to describe tendon injuries. Instead, beyond the initial acute injury, the terms *tendinopathy* and *tendinosis* are increasingly used to describe chronic tendon disorders.

Anatomy

The shoulder joint is one of the most complex joints in the human body. In discussing rotator cuff tendinopathy, we will be referring to the *glenohumeral joint*. This joint is composed of the glenoid fossa (socket) of the scapula (wing bone) and the head of the humerus bone (upper arm bone). Because of the structure of this joint, a human is able to reach up overhead and across the body or even scratch his or her own back, a remarkable range of possible motions for one joint. However, because of this extreme range of motion, the body needs many large and small muscles to hold the glenohumeral joint in place. The rotator cuff, composed of four muscles, acts as the primary source of this stability. The four muscles are the supraspinatus, infraspinatus, teres minor, and subscapularis. They form a roof over the head of the humerus, securing it in the glenoid fossa.

Among the four rotator cuff muscles, the supraspinatus muscle and tendon are the most commonly injured. This is thought to be partly due to their anatomical location in the shoulder. The supraspinatus muscle courses from an attachment on the scapula outward to its tendinous attachment on the humerus. As they pass over the head of the humerus, the muscle and tendon travel underneath a forward projection of the scapula called the acromion process (Figure 1). As the glenohumeral joint moves, the supraspinatus structures can be pinched in between the acromion and the head of the humerus, causing injury.

Causes

Two separate forces cause rotator cuff tendinopathy. These are commonly referred to as the *intrinsic* and *extrinsic* mechanisms. Intrinsic forces refer to changes in a tendon, and extrinsic forces refer to factors involving the structures surrounding a tendon.

The intrinsic mechanism refers to overload and degeneration of the tendon with sports activity. A tensile force placed across the tendon of a rotator cuff muscle during a contraction of the muscle can cause overload and eventual breakdown of the inherent tendon structure. Repetitive tensile overload especially puts the tendon at risk for injury. A baseball pitcher provides a good example for this. As a pitcher decelerates his or her arm after releasing the ball, the rotator cuff muscles around the shoulder contract in order to help stabilize the joint, placing a large amount of force across the tendon. Repetition of this motion hundreds of times can predispose the tendon to breakdown and continued degeneration.

The extrinsic mechanism refers to the compressive forces applied to the tendon from the surrounding

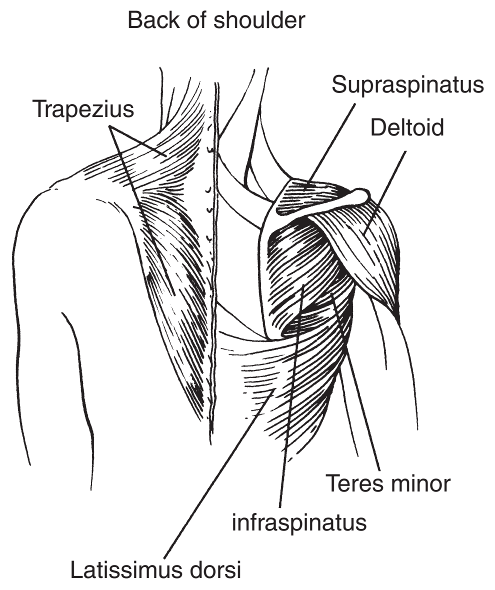

Figure 1 Muscles of the Shoulder

Note: Back view, showing the muscles of the rotator cuff.

structures. Various structures in the shoulder can be the source of compression, the most common being the undersurface of the acromion process. As the arm is brought overhead, the rotator cuff muscle or tendon can become entrapped between the humeral head and the acromion. This may cause microdamage, including contusion or tear to the tendon and muscle. This microdamage causes inflammation and dysfunction within the muscle, causing more instability and secondary compression and breakdown, thus creating a degenerative cycle of injury.

Symptoms

Athletes with rotator cuff tendinopathy will complain of pain with any overhead activity. Initially, the pain will only occur during the causative sport-specific activity, but it may progress to include normal daily activities, such as putting on a shirt or brushing their hair, as the severity of the tendinopathy increases. The shoulder pain will often be present at night, especially when lying on the affected shoulder. Apart from pain, athletes will also experience a measurable decline in performance, such as decreased speed or accuracy in a pitcher or decreased endurance in a swimmer.

Diagnosis

To determine if an athlete's shoulder pain is due to rotator cuff tendinopathy, a complete shoulder exam is required. The physical exam will begin with a thorough neck exam to make sure that a nerve problem in the neck is not the cause of the shoulder pain. During exam of the shoulder, the athlete will be asked to move the shoulder through all planes of motion, to look for deficits. If rotator cuff tendinopathy is present, the athlete will have pain with movement and in particular when bringing the arm over the head, a motion commonly referred to as the "painful arc." Other findings on the physical exam consistent with rotator cuff tendinopathy include weakness with rotator cuff strength testing as well as a positive Neer test or Hawkins-Kennedy test. The Neer and Hawkins-Kennedy tests attempt to cause external compression of the rotator cuff and consequently re-create the patient's pain.

X-rays may be used during the initial evaluation of shoulder pain. The size and shape of the acromion can be assessed to determine the likelihood of compression of the rotator cuff against this structure. Otherwise, in the athletic population, not much is learned from plain X-rays.

Apart from X-rays, two other imaging modalities may be used to explore for evidence of rotator cuff tendinopathy. One imaging technique commonly used is magnetic resonance imaging (MRI). An MRI scan is used to determine the extent of injury and may show inflammation or injury within the rotator cuff tendon, atrophy (shrinking) of the rotator cuff musculature, or extra fluid surrounding the affected tendon-muscle structure (a response to injury). Ultrasound can also be used to determine the extent of injury if rotator cuff tendinopathy is suspected. In addition to what is noted on the MRI scan, an ultrasound evaluation can be used to assess the health of the affected tendon and to note any microdamage of that tendon or even of the humeral head.

Diagnosis can be made based on the symptoms and physical exam alone. However, further imaging with X-ray, MRI, or ultrasound can be used to help confirm the diagnosis and to aid in creating the athlete's treatment plan.

Treatment

The basic treatment of rotator cuff tendinopathy can be divided into *acute* and *subacute* therapy. In the absence of a severe rotator cuff tear, the treatment of rotator cuff tendinopathy is nonsurgical.

Acute Therapy

Acute therapy is required after the initial evaluation of the athlete, particularly if there is significant shoulder pain or dysfunction. This therapy consists of rest, cryotherapy (ice), and nonsteroidal anti-inflammatory medications (NSAIDs; e.g., ibuprofen). To have proper rest, the athlete must avoid any aggravating activity, including all overhead motion. Cryotherapy can be used in the first few days following diagnosis to aid in pain relief and help reduce inflammation. NSAIDs are believed to also aid in pain relief and the reduction of inflammation. These medications are typically used for 10 to 14 days during the acute period and only as needed thereafter.

If there is significant pain and dysfunction, a referral to a certified physical therapist (PT) or doctor of physical therapy (DPT) may be pursued for additional acute adjunct therapies. These may include electrical stimulation (E-stim), phonophoresis or iontophoresis, and therapeutic ultrasound. These additional therapies may also be performed by a certified athletic trainer (ATC) if the athlete has access to one. Phonophoresis and iontophoresis use sound waves and electrical current, respectively, to push anti-inflammatory medication through the skin to the site of injury. An additional adjunct therapy that may be used for the treatment of rotator cuff tendinopathy is acupuncture.

Subacute Therapy

Physical Therapy

The use of physical therapy for the treatment of rotator cuff tendinopathy has a variety of goals. Acute therapeutic goals, as discussed above, include pain relief and the reduction of inflammation. Thereafter, the next goal should be to achieve the return of full, nonpainful range of motion in the shoulder joint. For the most part, physical therapy cannot be progressed until full range of motion has been achieved. After this motion is regained, the therapy will then be used to restore the strength and function of the rotator cuff muscles. In addition to strengthening the four rotator cuff muscles, the rehabilitation program will aim to restore the function of all the muscles surrounding the shoulder, including those that control the movement of the scapula.

At the end of a routine rehabilitation treatment program, the patient will be able to return to normal activities of daily living. However, in the treatment of athletes, the goal lies far beyond these basic activities. Sports place much greater demands on the shoulder joint than normal activities of daily living. Therefore, after full range of motion and strength have been restored, the athlete will be guided through a sport-specific prehabilitation program. The additional prehabilitation aids in the return to sport-specific activity by simulating the demands of the athlete's sport. For example, tennis players may perform a service-type motion using a 5-pound dumbbell as they progress back to sport.

Other Treatments

Most athletes will find improvement and/or resolution of symptoms with the above treatments. However, if no improvement is seen in 2 to 3 months, other methods of treatment should be considered:

Steroid injection: Often in sports medicine, a physician will use an injection of a steroid solution into a joint if chronic inflammation is thought to be the cause of the joint pain and dysfunction. Shoulder pain is no exception, and steroid injections are often used for the treatment of rotator cuff tendinopathy. A glucocorticoid solution is the medicine used for injection, in combination with a local anesthetic such as lidocaine or marcaine. Typically for rotator cuff tendinopathy, the goal of injection is instillation of medicine into the subacromial space, the area between the acromion and the head of the humerus.

Surgery: In the absence of a rotator cuff tear, surgery is rarely indicated for rotator cuff tendinopathy. However, if there is no improvement in the athlete's shoulder pain after completing 3 months of the above therapies, surgical exploration may be considered. Minimally invasive arthroscopic surgery is performed to confirm the diagnosis and, if present, to repair the damaged rotator cuff tissue.

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See also Musculoskeletal Tests, Shoulder; Principles of Rehabilitation and Physical Therapy; Shoulder Bursitis; Shoulder Impingement Syndrome; Shoulder Injuries; Shoulder Injuries, Surgery for; Tendinopathy

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Rowing, Injuries in

Rowing is a sport that has existed for centuries and was one of the first sports included in the modern Olympics. It consists of two main categories: *sweep rowing* and *sculling*. In sweep rowing, sometimes referred to as crew, each rower holds one oar and places it in the water on the rower's right (starboard) or left (port). Sweep events include the pair, four, and eight. While the eight always has a coxswain (the person who steers the boat and commands the rowers), there are separate event categories for the pair and four with coxswain (coxed pair and coxed four) and without coxswain (straight pair and straight four). In sculling, each rower has two oars and places them in the water simultaneously on each side of the boat. Sculling events include the single, double, and quad (one, two, and four rowers, respectively).

The rowing stroke is composed of four different parts: the catch, drive, finish, and recovery. At the catch, the body is fully compressed, and the oar handle is rotated and lifted to place the blade into the water. The drive consists of extending the legs and then swinging the back past 90°. At the finish, the arms carry the momentum generated by the legs and back by pulling the handle to the body and then pressing the oar down and rotating it out of the water. The final phase of the stroke is the recovery, the reverse of the prior two phases. Here, the arms extend away from the body, the body pivots forward at the hips, followed by the legs compressing back into the catch. The rower moves on a seat with wheels in the boat while repeating the phases of the stroke.

In addition, there are two weight categories: open weight (no weight restriction) and lightweight (in general, 126-pound (lb) boat average with 130-lb individual maximum for women and 155-lb boat average with 160-lb maximum for men). There are slight variations to these rules depending on the event and regatta. The weight control methods of lightweights should be monitored, as excessive caloric restriction and other weight loss techniques can increase the risk of injury and illness. Lightweights are at risk for eating disorders, and female lightweights are at risk for the female athlete triad, both of which are addressed in other entries of this encyclopedia.

Rowing on the water or performing the rowing motion on an ergometer (on-land rowing machine) has great cardiovascular benefits as well as skeletal benefits for the spine. However, because rowing involves repetitive movements, this sport can lead to overuse injuries. This risk is increased as rowers aggressively increase training loads on the ergometer, on the water, and in the weight room. Tissues adjust to increased training loads at different rates. Muscles adapt most quickly, followed by bones, ligaments, tendons, and then cartilage. Thus, in addition to muscular injuries, as loads are increased when muscles adapt sufficiently, excessive strain is placed on the other tissues, leading to fractures, inflammation, and/or tears.

During the drive, up to 4.6 times the body weight is loaded on the lumbar region. Along with back extension and flexion, sweep rowing involves a twisting motion of the spine in the direction of the oar. The back is therefore the most commonly injured site in rowing. Injuries include vertebral disk problems (bulges, herniations, etc.), spinal fractures (spondylolysis and spondylolisthesis), and muscle strains. Even the sacroiliac (SI) joint may sometimes become painful because of rotational stress at the site, leading to partial shifts in a joint that is typically nonmoving.

The repetitive strain on the upper body may also lead to rib stress fractures and/or muscle and cartilage injuries near the ribs. The rowing stroke involves simultaneous activation of the intersecting serratus anterior and external oblique muscles, which both attach to the ribs and have partially opposing actions. This can cause strain at the ribs, sometimes leading to a stress fracture. The intercostal muscles are located between the ribs and help move the chest wall with inspiration and expiration. These too can become injured with repetitive deep breathing and resistance throughout the stroke. Costochondritis (inflammation where the ribs attach to cartilage at the sternum) may also be a result of this overuse.

While the power needed to propel the boat through the water largely comes from the back and legs, the placement of the oar(s) in the water and the turning of the oar handle when removing the oar from the water (feathering) require upper extremity dexterity. Without a relaxed, proper grip on the handle, athletes may develop wrist and forearm complaints such as carpal tunnel syndrome and intersection syndrome (crossover tendinitis: inflammation of the tendons that cross over one another in the forearm).

Significant leg injuries are less common in rowers than injuries in other areas of the body, but the hyperflexion and extension of the knee at the catch and finish of the stroke, respectively, can lead to knee pain as the knee cap (patella) shifts (patellofemoral syndrome) and the iliotibial (IT) band on the outside of the leg becomes tight (IT band syndrome). There have also been cases of hip labral (lining) injury, believed to have occurred from the extreme flexion and extension rowers use in the sport. In the upper and lower limbs, numbness can sometimes occur when nerves become entrapped as muscles swell and are not properly, regularly stretched.

Finally, because of the contact of the hands with the oar, the buttocks with the seat, and the calves with the tracks on which the seat slides, these areas are all at risk for skin abrasions, calluses, and infections.

Most rowing injuries may be prevented with good technique, appropriate stretching, strengthening of the opposing muscles, and decreasing the volume of activity or cross-training when pain begins. However, when the pains do not resolve with conservative measures, the athlete's technique should be scrutinized, and he or she should be evaluated by a health professional. Physical therapy and modification of technique may improve muscle strains and tendinitis. Rest and bracing may be needed for more serious injuries. Surgery for vertebral disk injuries, carpal tunnel syndrome, patellofemoral pain, and labral tears is recommended only for recalcitrant cases.

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See also Carpal Tunnel Syndrome; Eating Disorders; Female Athlete Triad; Iliotibial Band Syndrome; Patellofemoral Pain Syndrome; Skin Disorders Affecting Sports Participation; Skin Infections; Spinal Cord Injury; Sunburn and Skin Cancers; Tendinitis, Tendinosis

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Rugby Union, Injuries in

Rugby union is a highly physical game played by more than 3 million men, women, boys, and girls ranging in age from 6 to 60 in more than 100 countries across five continents. It is a collision team sport with a significant risk of injury. Injuries can be sustained by every part of the body, but the injury profile of the game is relatively consistent with respect to which injuries occur most commonly and which cause the greatest numbers of days lost from playing and training. Those providing medical care to rugby union players need to offer best-practice treatment protocols for these injuries and develop specific injury prevention strategies for the injuries that cause the greatest numbers of days of absence.

The Modern Game

The game is played by two teams of 15 players each on a field measuring a maximum of 100 meters (m) by 70 m plus 2 m in goal areas. Teams attempt, by carrying, passing, kicking, and grounding the ball, to score as many points as possible. The laws of the game, governed by the International Rugby Board (IRB), aim to minimize the risk of injury and ensure that the game is played in a sporting spirit by people of all shapes and sizes while emphasizing that the contest for possession is paramount. There are specific law variations for those under 19 years of age and for seven-a-side rugby union. Senior rugby is a collision sport consisting of two 40-minute halves, comprising passages of open play interspersed with up to 500 contact/collision events per game, approximately 50% of which are tackles (where one or more tacklers attempt to stop or impede the ball carrier with the use of their arms) and 25% are rucks (where players from both sides attempt to drive over the grounded, tackled player and ball). A maul develops when a tackled player is not forced to the ground and players attempt to wrestle the ball free. A unique element of the game, the scrummage, is used to restart play after a range of infringements. Eight forwards from each side link arms in a 3-4-1 formation, and the players in the front rows of each pack of eight lock heads with their opposite numbers. A lineout is used to restart play if the ball passes out of play over the sideline. Here, the team that did not send the ball out of play throws the ball down the middle of two lines comprising at least two players from each team, who compete for the ball in the air.

Rugby Union Injuries

Incidence

Injuries occurring during matches constitute the largest proportion of the rugby-related injuries reported, typically accounting for 80% to 90% of all injuries. The great majority of match injuries are the result of direct contact with an opposing player. The risk of sustaining an injury in a rugby union match appears to be higher than in many other sports irrespective of the definition of injury. However, the incidence is much lower in senior amateur (15–74 injuries per 1,000 player-hours), schoolboy (7.0–28), and women (3.6–7.1) players than in professional players (68–218). The severity of rugby union injuries is typically reported in terms of days lost from playing and training. The average elite senior game typically results in two players from each side being injured for an average of 18 days each.

Injury Profile

The lower limb is the most common location of injury, with the proportion of injuries sustained ranging from 41% to 55%. More specifically, the knee, the thigh, and the ankle are the sites most commonly injured. Also, injuries to the lower limb, in particular knee joint injuries, appear to be disproportionately severe. Medial collateral ligament (MCL), chondral/meniscal, and patellofemoral/extensor mechanism injuries are the most common knee injuries; however, anterior cruciate ligament (ACL) and MCL injuries cause the greatest number of days of absence. Thigh hematomas

Rugby union scrum. Due to the frequent physical contact in the game, the incidence of collisions is relatively high, as is the risk of sustaining an injury.

Source: Can Stock Photo.

("dead legs") and hamstring muscle strains are the most common thigh injuries; the impact of hamstring muscle injuries, in particular, on the overall injury burden may be reduced by appropriate eccentric hamstring training and complete rehabilitation of these injuries. Lateral ankle ligament injuries are the most common ankle injury and, together with Achilles tendon injuries, make up the greatest proportion of ankle injuries that lead to absence from play and training.

Head and noncatastrophic neck injuries frequently represent the next highest proportion, ranging from 12% to 33% of all injuries, although variations in the definition of injury employed can alter these proportions significantly. Lacerations to the head and face and concussions are the most common head-and-neck injuries, followed by facial fractures.

The upper limb represents a smaller proportion of the injuries (15%–24%); of these, shoulder injuries are the majority. Shoulder injuries also appear to be disproportionately severe. Acromioclavicular joint and rotator cuff injuries are the most common shoulder injuries, although shoulder dislocations and clinical episodes of shoulder instability lead to the greatest number of days lost from play and training. The injury profile in schoolboy players is similar to the profile seen in senior players but is characterized by a higher proportion of upper limb injuries.

Injury Events

Tackles are the match event responsible for the highest number of match injuries and the greatest time lost from play and practice because they are by far the most common contact event. The relative propensities (assessed by comparing how often an event is associated with injury against the frequency [%] with which the event occurs in the game) of contact events to cause injury are scrum and collision, high; maul and tackle, average; ruck, low; and lineout, very low.

Specific Injuries

Catastrophic Spinal Injury

Nonfatal catastrophic (spinal) injuries have received considerable focus in the medical literature due to their devastating consequences. These are defined as a brain or spinal cord injury that results in permanent (>12 months), severe (>50% loss) functional disability and is usually the consequence of a fracture dislocation of the cervical spine (at C4-C5 or C5-C6). Nevertheless, these injuries are extremely rare, with a historical aggregated worldwide incidence of between 1 and 5 cases per 100,000 players per season. The vast majority (approximately 80%) of cases are split equally between the scrum and the tackle. There have been a number of changes to the laws of the game in an attempt to reduce the risk of these injuries. In January 2007, the process by which the two front rows come together (engage) at the scrummage was modified in an attempt to reduce the force of impact and further control the engagement process. Early reports on the consequences of this law change are positive. The importance of optimal on-the-pitch management, appropriate cervical immobilization, and urgent transfer to a specialist unit in optimizing the long-term outcome of these injuries cannot be overstressed.

Concussion

The incidence of concussion in the elite game is reported to be 4.1 per 1,000 player-hours. Concussion in rugby union is evaluated and managed by standard clinical procedure. Subsequent return to play is guided by IRB Regulation 10, which states that the concussed player should undergo a mandatory 21-day stand-down from playing and training unless he or she is symptom-free and is cleared to return to play by an appropriately qualified neurological specialist. Approximately half the asymptomatic elite players with access to specialist medical advice return to play in 7 days or less. At the under-19 level and below, the 21-day stand-down is mandatory.

Blood Injuries

The laws of the game allow for the temporary replacement of a bleeding player for up to 15 minutes so that the bleeding may be controlled. In all other circumstances, the replacement of an injured player is permanent and cannot be reversed during a game.

Injury Prevention Strategies

General

Rugby injury causation is multifactorial in nature, and injury prevention strategies need to minimize the effect of the interplay between

- intrinsic player risk factors (typically by increasing the resilience of the player to injury through conditioning and prehabilitation initiatives) and
- exposure to extrinsic risk factors (typically by protecting the athlete by optimizing the player's technique in all elements of the game and ensuring that the laws of the game are consistently applied).

Comprehensive injury prevention programs (such as New Zealand's RugbySmart program) are increasingly showing that a reduction in injury risk is achievable without altering the essential nature of the game.

Padded Equipment and Headgear

One potential method of reducing injury risk is by the wearing of padded equipment and mouthguards; although there is no stipulation that this equipment must be worn in the laws of the game. The thickness and density of the shoulder pads, headgear, and chest pads that may be worn during matches is restricted by the IRB. Research to date indicates that padded headgear does not reduce the incidence of concussion in rugby union and shoulder pads do not reduce the incidence of shoulder injuries, although a reduction in the incidence of superficial scalp and facial injuries in selected positions when headgear was worn has been demonstrated. Mouthguard use, principally to reduce dental injury, is strongly encouraged but not mandated in rugby union.

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Running a Sports Medicine Practice

During the past half-century, numerous major advancements in medical science and technology, performance enhancement, and injury prevention and rehabilitation have had an impact on sports medicine. While these improvements have not dramatically changed the nature of sports medicine, they have changed its practice. In a period of rapid change, the demands of modern sports medicine, combined with changes throughout the health care system, have required new ways of organizing and managing the business of a sports medicine practice.

Sports medicine is the medical subspecialty that is generally concerned with one overarching mission: the prevention, diagnosis, and treatment of illness and injury related to participation in any athletic exercise or contest. To accomplish a mission as comprehensive as this, much depends on having a multidisciplinary, complementary approach to health care delivery that uses both operative procedures and nonsurgical techniques. This has been the basic element of sports medicine practice since the days before Galen's remedy for wounded tendons led to his appointment as physician to the gladiators in Greece during the second century CE. But more recently, several significant social transformations have made new demands on the practitioners of sports medicine.

More than at any other time in history, the 20th century brought to sports at least two interrelated changes that had a direct bearing on sports medicine:

(1) the increasing specialization of the medical profession, in large part due to the rise of people who used their knowledge and learning as a basis for developing skills that allowed them to perform highly specialized, productive work in fields such as athletic training, physical therapy, nutrition, psychology, sport science, and coaching; and (2) increased access to, news about, and participation in recreational-, amateur-, and professional-level athletic activity. The latter of these changes alone required that medical practitioners be knowledgeable about a wide array of physical, physiological, psychological, and environmental factors across a diverse population. What emerged as a result was a context of sports medicine that gave a new status and function to its practitioners.

This new reality encouraged the establishment and proliferation of sports medicine clinics. The sports medicine clinic intends to provide a single location in which all manner of evaluation, testing, and treatment can be offered to the patient-athlete. The comprehensive activities of analysis and prescription that occur within it are performed by a cooperative variety of specially educated, trained, and experienced practitioners. Sport medicine clinics are wide-ranging in size and function and often go beyond the domain of physicians and surgeons to include athletic trainers and physical therapists, coaches and sport scientists, nutritionists, psychologists, podiatrists, chiropractors, masseuses, and other such professionals.

Today's sports medicine clinics are an outgrowth of partnerships such as that of Robert Kerlan and Frank Jobe, who began acting as physicians and orthopedic consultants to a number of professional sports teams in the United States during the mid-1950s and 1960s. Although a good many physicians and surgeons throughout the world—and especially in Europe—had for centuries contributed to the development and breadth of sports medicine, the practice and clinical research led by Kerlan and Jobe produced numerous innovative surgical procedures that were in turn used to treat any patients who required orthopedic care.

While such enterprises have since become increasingly commonplace, sports medicine continues to be practiced and administered in clinical settings of all sizes, extents, and locales. For instance, family medicine physicians and physiatrists, like orthopedic surgeons, have built on the training of their residency programs by undergoing subspecialty training in sports medicine. As subspecialists, they can command higher rates of insurance reimbursement for clinical work and have to deal much less with traditional family medicine responsibilities such as overnight calls and patients who are hospitalized for longer periods of time. But regardless of the pathway one takes, the leadership of a sports medicine practice requires the competence, skill, and responsibility of a physician, as in any medical practice.

Tasks, Demands, and Implications

The term *sports medicine* denotes a specific practice area. But it is not adequate to reduce its function and work to a single description. Sports medicine physicians, often with the assistance of various medical staff and administrative personnel, may practice in clinics, private offices, and in athletic teams' facilities. Though these practices are among the few health care businesses that remain consistently lucrative, sports medicine is not immune to all the forces that have an influence on medicine and health care today. And they are also affected by many of the same forces that have an impact on any of today's small- and medium-sized businesses.

As for any organization, the first and most important question in managing a sports medicine practice is to determine its specific purpose and mission. What the practice sets out to do, how it will perform, what impact it will have, and what services it will discharge for the benefit of patients and the community are of utmost importance. The basic definition of the practice governs the types of patients it will provide care for and how it will go about doing so.

Because patients have individually different reasons for accessing the sports medicine practice, the physician, as leader of the practice, must define the mission accordingly. This is achieved not by looking at what the physician thinks the practice should be but by looking at the needs, interests, expectations, and values of existing and potential patients. Constant changes in population structure and behaviors can make this a difficult task. Yet the physician has to pay attention to which aspects of the practice will satisfy the patient. The physician must therefore decide on what parts of the practice should be maintained or abandoned and how those decisions fit the purpose and mission. Such consideration helps the patient better understand the services offered by the practice; it also helps employees of the practice better understand how and where they contribute to the endeavor.

Of further consideration for the physician and other managers of the practice is how the practice will attract patients and employees and to what type of facility. There is a consequent need to consider objectives, such as for human resources and capital, financial planning and investment, marketing, information, and technology. There is also a need to think through what results will be expected, how they will be qualified and quantified, and how the aforementioned resources will be used to influence those results. And results are further achieved by recognizing the relative strengths of the practice and the people within it. By defining the mission and converting it into results that are oriented toward action, the performance of the practice can then be planned.

Any of the tasks and demands of a modern sports medicine practice must be measured against the reality that medicine and health care have undergone rapid and enormous changes in the past 40 years or so. Although sports medicine physicians are at times positioned above the fray, they too have come to realize that the professional lives of physicians are increasingly defined by group practice relationships, health maintenance organizations, and corporate and government versions of "managed care." During this span of time, physicians have reported perceptions of decreased control over medical decisions and referral processes and ethical concerns related to the compliance requirements of legislation such as the Health Insurance Portability and Accountability Act (HIPAA). Within these concerns is the potential for some treatment options and explanations to go unexplored due to time, financial, and accessibility constraints. Another subtext that has gained attention of late is the relationship between medical professionals and the pharmaceutical and medical device industries. But there is a range of other professional ethical issues specific to sports medicine that must be regarded to varying degrees depending on the type of practice.

One of the primary responsibilities of any physicians is to keep the patient well-informed about care and treatment options. When it comes to caring for the athlete, the physician must balance the health needs and the athletic goals of the patient—and the two are not always in accord with each other. Sports medicine has historically sought to provide a means of enhancing athletic performance while preventing athletic injury. But as fame and fortune through athletic feats have increased over time, the focus on performance enhancement has superseded the interest in injury prevention, and some of the traditional boundaries of clinical practice have been diminished in the practice of sports medicine. Today's sports medicine physician must be prepared to readjust thinking about how to behave with regard to patient confidentiality and third-party knowledge, informed consent, treatment methods and decisions about return to competition, use of performance-enhancing and recreational drugs, the application of new technology such as genetic engineering, and advertising of services. These factors are especially serious for the team physician, who must also consider any conflicts of interest because of arrangements and affiliations with different sports teams.

As more people participate in more sports and continue to develop even new ones, it is difficult to adequately estimate the extent of sports medicine in today's world. But it is easy to recognize that the precepts that held true in the sports medicine of antiquity are the basic elements around which today's sports medicine practices can organize and manage their business.

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Running a Strength Training and Conditioning Facility

The day-to-day operation of a strength and conditioning facility requires a dynamic and knowledgeable staff. Of utmost importance to the staff is the safety and progress of the athletes in training. To provide superior support and guidance, the staff must have superior knowledge, the ability to respond effectively in case of an emergency, and equipment that has been proven safe and effective. The following text will provide guidelines and suggestions to effectively run strength and conditioning facilities for athletes.

Personnel

Recruiting and Staffing

Staffing a strength and conditioning facility is a high priority to ensure effective assistance for athletes in attaining their strength and conditioning objectives for their particular sport. The management, owner, or recruiter who is hiring training staff for the facility should consider the following criteria:

- Applicants should have a degree from an accredited university or college in exercise science or related coursework that highlights exercise physiology, human anatomy, biomechanics, nutrition, exercise prescription, sport psychology, and kinesiology. The National Strength and Conditioning Association has adopted an Educational Recognition Program that provides a list of institutes that meet or exceed these requirements. A bachelor of science (BS) degree is an excellent start for any person who is seeking a career as a strength and conditioning coach; a master of science (MS) degree is preferred by recruiters.

- Personnel with degrees in exercise science or related disciplines should have a minimum of 4 years of coursework and practical application through internships and practicum requirements. Many of these courses, as well as hands-on experience, prepare them for secondary certifications. All strength and conditioning coaches must be certified to administer cardiopulmonary resuscitation (CPR) and to use an automatic external defibrillator (AED). Professional certification organizations requiring continuing education as well as adherence to codes of ethics will increase the credibility of a strength coach's candidacy. The most widely recognized certifying bodies are accredited through the National Commission for Certifying Agencies (NCCA). The American College of Sports Medicine (ACSM), National Strength and Conditioning Association (NSCA), American Council on Exercise (ACE), and National Academy of Sports Medicine (NASM) are among the recognized certifying agencies that strength coach candidates should seek out for credibility. Each organization has different scopes and specialties, so the strength coach seeking additional credibility should research the agencies from which he or she is seeking certification.

- Strength coaches have greater credibility when they have aligned themselves with other health professionals to create what the NSCA calls a "performance team." This is when a candidate or staff has been teamed with other fitness professionals whose specialties complement the specialties of others on the team. For example, a performance team may include a strength coach, nutritionist, athletic trainer, massage therapist, and team physician. This team will help the athlete achieve greater results, especially if the common goal is increased athletic performance and decreased propensity to injury. A dynamic staff with complementary skill sets not only helps the facility to run smoothly but also, by its comprehensive expertise, can prevent the occurrence of incidents that could result in personal injuries and consequent lawsuits.

Staffing Hierarchy and Responsibilities

The staff hierarchy in strength and conditioning facilities is usually different from that of public fitness centers. Apart from the performance team, the staff in the strength and conditioning facility includes a head strength coach, one or more assistant strength coaches, and student coaches or interns. The head strength coach is responsible for all exercises that are implemented to improve the strength and conditioning of the athletes and all other facets of the facility. Some of those facets include, but are not limited to, scheduling the athletes' training times, developing staff skills, delegating staff to athletes and teams, setting up staff hours and responsibilities, keeping open the channels of communication with the performance team and team coaches, and keeping the equipment up-to-date and safe.

Facility

Several very important components factor into the space used for the facility: the square footage that makes up the strength and conditioning facility, the layout of the equipment (i.e., the floor plan), and the location relative to the location of the athletes who will be traveling to the facility.

Location and Program Needs

Determining the location of the facility depends on several variables. First, what is the demographic? Is it composed of youth, high school, or collegiate athletes in the towns or amateur and professional athletes in a state or region, who will be migrating to the facility for their conditioning needs? Second, how many athletes will use the facility? Third, what are the strength and conditioning needs of the athletes who are going to be using the facility? Then, how will the conditioning work into the athletes' schedules? Last, what is the training age of the athletes using the facility?

If the demographic is youth and high school athletes, it is necessary to have the facility allow for the drop-off and pickup of the young athletes. The facility should also have plentiful parking near the facility to accommodate team buses or vans. If the demographic is made up of amateur- or elite-level athletes from the surrounding towns or counties, the facility should be located near major routes so that the commute to the center is simple and accessible.

It is necessary to know how many athletes will be using the facility at peak time. For example, with high school athletes, the strength coach needs to know the maximum capacity of the facility for the safety of the athletes who will be conditioning at one time.

When considering the athlete's conditioning requirements, the head strength coach will need to know the particular requirements of the sport that the athlete plays and the training age of the athlete using the equipment. For example, the ratio of Olympic lifting equipment to resistance training machines may be higher for amateur athletes than for middle school or high school populations, which are relatively new to resistance training. Another consideration is the type of athlete using the facility. If the athletic population is primarily football players, then the need for free weights, plyometric boxes, and Olympic lifting stations is higher than the need for resistance training machines, which would be more applicable to athletes recovering from injury.

It is very important to fit strength and conditioning into the athlete's schedule. The performance team must work together with athletic directors, sports medicine teams, and the governing body that dictates the regulation of the athletes' contact time with coaching staff. For example, the NCAA directs the coaches of collegiate sports teams (with the exception of the strength and conditioning coach) as to the number of formal practices they can have with their athletes during the off-season semester.

Space Considerations

Once a location is found that meets the needs of an effective facility, the design of the strength and conditioning area must also fulfill several requirements:

- Accessibility
- Observation location
- Ceiling height
- Flooring needs
- Environmental factors

Accessibility

Accessibility of the strength and conditioning facility has several implications. Accessibility of the center refers to which floor it is on, the size of the doorways and walkways, and whether these doorways and walkways are unobstructed. The ground floor is ideal for a strength and conditioning facility due to the heavy weights and machinery that will be loaded onto the floor. If the facility is not on the ground floor, then the flooring needs to be stable enough to avoid any structural damage from dropping weights or other heavy equipment. The minimum requirement for load-bearing capacity is 100 pounds/square foot (ft^2), or 488 kilograms/square meter (m^2). To complement the floor's load capability, it should also have sound-absorbing features to avoid disturbance to the dwellings, offices, and classrooms nearby.

Doorways and walkways need to be accessible for the handicapped and large enough to move equipment in and out of the facility. All doors in and out of the strength and conditioning floor must be double doors with a removable middle post. All doorways must remain free of obstructions, especially the emergency exits. These exits must also be well marked with standard lit signs above the doorways.

Observation Area

It is imperative for the strength coaches to have a full view of the strength and conditioning floor, therefore the viewing room or office must have large windows that allow the staff to see all areas when they are not on the floor.

It is recommended that ceiling height have 12 to 14 ft (3.66–4.27 m) of clearance with low-hanging items such as fans; lights; heat, ventilation, and air-conditioning (HVAC) systems; or sprinkler systems. For all structural elements, local building codes must be observed.

Flooring

Flooring needs are very simple in strength and conditioning facilities. The flooring is either carpeting or heavy-duty rubberized material. Carpeting can provide a softer look to the facility and can be any color. It should be located in areas of the strength and conditioning facility where cardiovascular conditioning and stretching are performed. Carpeting should be antibacterial and durable. Rubberized flooring can also be of different colors, thicknesses, and textures. The best thickness for flooring is ⅛ to ¼ inch (in.; 1 in. = 2.5 centimeters). Rubberized flooring is designed as interlocking squares or mats that can be rolled out for large areas. If there is a large enough budget for the facility, then having rubber flooring poured in is the best option due to its durability. More important, there are no seams that the athletes could trip on, or that could become unsanitary over time. It is important to note that if the facility is to have a combination of carpeting and rubberized flooring, it is important to have a smooth transition between the two areas, either with beveled edges from the carpeting to the rubber flooring or having the two areas flush with each other.

Environmental Factors

The training conditions of the facility should be controllable. Lighting, humidity, temperature, circulation, and sound are factors that need to be kept consistent to optimize the environment for strength and conditioning of athletes. The facility needs to be well lit with overhead fluorescent lighting and with windows to allow natural light in as well. Well-balanced lighting throughout the facility allows for better maintenance of equipment and the overall cleanliness of the facility, and the strength coach will be able to better watch the athletes executing the exercises. When setting up the layout for equipment for the facility, it is important to be cognizant of glare from mirrors or from sunlight through the windows, so that when the athletes are performing an exercise, their attention is not distracted by blinding light.

HVAC systems are key to successful training in a strength and conditioning facility. When athletes are exercising in very cold or very hot temperatures, body systems can be taxed to physically dangerous levels. The ACME recommends that the temperature range be between 68 °F and 72 °F (20 °C–22 °C), whereas Armitage-Johnson suggests having the temperature of the facility between 72 °F and 78 °F (22 °C–26 °C) with a relative humidity of 60%. It is preferable to have HVAC systems that can be controlled in different areas or zones of the facility so that warm-up and cooldown areas are slightly warmer than the high-intensity strength and conditioning areas. Indoor temperature should remain consistent because drastic changes in temperature in the facility can cause the relative humidity to increase and therefore cause damage to equipment due to corrosion. Some authorities recommend that an acceptable air circulation in a facility is 8 to 12 air exchanges per hour, while 12 to 15 exchanges per hour is an optimal level. Locker room air exchanges should be slightly higher, at an approximate level of 16 exchanges per hour. Depending on the ceiling height of the facility, ceiling fans can assist in maintaining the level of the air exchanges.

Miscellaneous Facility Layout Needs

Other things to be taken into account when considering the optimal operation of a training facility are electrical supply, telecommunications, storage, mirrors, signage, locker rooms, and water supply. Electrical outlets need to be relatively dense in areas where cardiovascular equipment is located and should be grounded at 110 volts (V). For larger pieces of equipment, such as treadmills, 220 V is necessary. Mirrors should be placed in areas where the form of particular exercises needs to be seen for visual feedback for the athlete and the coaches. Telecommunications include the location of the phone, cable jacks, and wireless routers within the facility. Telephone receivers should be wireless or cordless so that the coach has access to them while training athletes all over the facility. Having wireless Internet capabilities and laptop computers is preferred for immediate record keeping during strength training sessions and uploading data from testing batteries. Water fountains should be installed in strategic locations so that athletes can get to them quickly for hydration without extending the down time between exercises. Locker rooms should be equipped with shower facilities; there should be large lockers for athletic equipment, lavatories, and individual changing rooms. Some of these components may depend on the age and gender of the athletes.

Facility Layout

When deciding the optimal layout of the strength and conditioning facility, multiple factors come into play:

- Grouping like equipment
- Grouping like conditioning areas
- Flow of traffic
- Spacing of equipment

Grouping all strength equipment with similar functionality is convenient for the strength coach and the athletes for two main reasons. The first reason is that it is easier for the strength coach to observe and coach each athlete in a session when they are all together. When observing form and technique for high-level resistance training, the coach's attention should not have to be spread across the entire facility. The second reason for having like equipment in the same area of the facility is to allow athletes who are doing the same exercises to "spot" each other. Thus, athletes and programs can be scheduled so that there is proper spotting and no waiting for the different exercises.

When designing the transition between different conditioning areas in the facility, careful thought needs to be given to determining the locations of the stretching/warm-up, cardiovascular, power, and strength training areas. It is preferable to have the cardiovascular equipment in the carpeted area of the facility (if there is such an area) and near both a wall and a window. This will give the athletes more space for stretching and warming up. The stretching area should be in an area of the facility that does not obstruct the flow of traffic and allows athletes to have plenty of space, approximately 36 to 49 ft^2, depending on the size and number of athletes. Taller pieces of equipment should be placed against the wall, whereas shorter and smaller pieces can be placed in the center of the facility to allow better visibility for the coaches observing their athletes. The spacing of equipment depends on the type of equipment. Resistance training and cardiovascular training equipment can be much closer to each other than free weights. The general recommendation for a safe space between cardiovascular and resistance training machines is approximately 24 in., while the safe distance between free weight stations is 36 in., that is, 36 in. between the distal portions of the moving equipment. An example of this type of spacing would be the distance between two barbell bench press stations. Each station should allow for a minimum of three or four people to fit into the designated area, one athlete to perform the exercise and three other athletes to safely spot. This would be the case for power lifting exercises such as barbell squats. As for Olympic lifting stations, there should be 4 ft between the stations and room for three or four people in and around each station to rotate through.

Facility Maintenance and Daily Needs

It is crucial that the facility's cleanliness be maintained for the safety and health of the athletes. A cleaning and equipment maintenance checklist must be kept on a daily and weekly basis. If the resistance training and cardiovascular equipment is not maintained, the cost of repairs and replacement will strain the capital expenses budget. Chains, rods, and moving joints of equipment must be kept clean and well lubricated, allowing for smooth movement when athletes are exercising on the equipment. Assigning staff or interns to specific areas or equipment will result in a clean and well-maintained facility. If the facility's cleanliness is not kept up, the risk of a viral and/or staph infection increases; a single outbreak can affect an entire team and result in major performance setbacks at pivotal points in training or competition.

Scheduling Training and Conditioning of Athletes

Factors that dictate the scheduling of strength and conditioning sessions include the following: (a) whether the athletes are in-season, (b) the sport the athletes play, (c) the number of athletes on the sports team, (d) the skill level of the athletes, and (e) even the position that the athletes play in their sport.

Peak time in the facility depends on the athletes' outside obligations (school, work, or skills training or team practice). Early-morning training sessions are ideal for training athletes who are in-season when they have team practice in the afternoon, and vice versa. Athletes who are in-season have priority over peak times of the facility due to strict team practice schedules and to optimize training adaptations. Even though in-season athletes have priority, they do not usually spend a great deal of time on their conditioning (usually about 1 hour for 2–3 days/week), because they are in the maintenance phase of their training. During the off-season, athletes will come for training at a time adjacent to the peak times of the facility. Off-season athletes' off-field conditioning sessions are longer in duration (1.5–2 hours for 4 days/week) than in-season athletes' sessions since they do not always require to attend team practices on that same day. Athletes who are recovering from injury will come into the facility at nonpeak times so that they can work more closely with the strength coach during their rehabilitation process.

The strength coaches need to determine the maximum number of athletes who can use the facility at the same time, for two main reasons: (1) the risk of injury to the athletes if there is overcrowding and (2) the time potentially wasted if athletes have to stand idly waiting for space or equipment. For example, during the American football preseason, the increased volume of athletes challenges strength and conditioning facilities at universities and high schools because the facilities often are not large enough to handle the extra players. To have the appropriate number of Olympic and power lifting stations for a full football team would require more than 15 stations. The ratio of athletes to coaches must not exceed 10:1 in junior high facilities and 15:1 in high school and collegiate facilities, according to Armitage-Johnson. Therefore, at large schools and in professional team facilities, it is standard to have four or more strength coaches working with the athletes at once. If the athlete-to-coach ratio cannot stay within those requirements, it is important to stagger the athlete's training times at the facility. When the training sessions are staggered, the strength coaches are able to give each athlete the same amount of time to focus on the exercises that require the most attention to detail. Using the example of an American football team again, the strength coaches can work on each athlete's Olympic lifting technique equally if groups of four athletes are scheduled every 15 minutes. This enables the coaches to provide the necessary directions for a highly technical exercise.

Conclusion

Operating and staffing a strength and conditioning facility offers many challenges for strength coaches, athletic directors, and facility owners. If the coaches, owners, performance teams, and athletes all focus on the ultimate goal of improving athletic performance, the challenges will be minimized. Having quality equipment and knowledgeable strength coaches on the staff ensures that the athletes and team coaches will value conditioning as an essential step to achieving the ultimate performance goals.

Samuel L. Berry

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Running Injuries

Despite the growing popularity of rival fitness forms such as aerobic dance, mountain biking, in-line skating, stair-climbing, and cross-country skiing simulators, running remains a perennial favorite. Surveys show that more than 26 million adult Americans run regularly.

The appeal of running is obvious: Almost everyone can do it, it can be done almost anywhere and at any time, and it is inexpensive. Running not only continues to hold the interest of millions of Americans, but every year, it attracts legions of new participants drawn to its health benefits and unique advantages.

More than almost any other health fitness activity, however, running has a downside: injuries. Most runners at one time or another suffer from a running-related ailment that puts them out of action, sometimes permanently. It is estimated that 80% of runners sustain injuries.

Most debilitating running injuries could be prevented by addressing the initial symptoms before they develop into full-blown overuse injuries—namely, at the sport ache stage. A runner's sport ache is almost always related to one of these five components: exercise intensity, anatomical factors, conditioning, technique, and equipment. The runner who determines which of the above components has caused the running sport ache can manage the problem by addressing that component.

Exercise Intensity

Injuries can occur when runners substantially increase the frequency, duration, or difficulty of their training regimen. Frequency refers to how often they run, duration to how long they run, and difficulty to how hard they train. Frequency and duration are self-evident. Difficulty is more complex.

Not only does difficulty encompass factors such as how far or fast a person runs, but it also involves the type of surface the runner uses. Runners increase the difficulty of their training regimen when they switch from running on grass or clay to running on roads or from running on flat surfaces to running over hills. Softer does not always mean better. For instance, running on sand stresses the Achilles tendon and can cause tendinitis in that area in the back of the lower leg.

Because the body's tissues need time to adjust to the demands of increased repetitive motions, such as the impact of feet pounding against the running surface or the repetitive extension and contraction of the Achilles tendon, increases in the frequency, duration, or difficulty of a runner's training regimen must be gradual.

It is generally considered safe to increase the frequency, duration, or difficulty of a running regimen by 10% without making adjustments. But when substantially increasing the intensity of one of the three components of a running regimen, it is necessary to make temporary adjustments to one or both of the other elements:

Increase in exercise frequency ⇒
Reduce duration and/or difficulty

Increase in exercise duration ⇒
Reduce frequency and/or difficulty

Increase in exercise difficulty ⇒
Reduce frequency and/or duration.

By how much, though, should the runner cut back? When runners intensify one element of their training regimen, they should cut back on the other two elements of their training regimen by 20% and then increase them by 5% each week until they have reached their previous level. For instance, if it takes a runner 1 hour to run 5 miles, and he or she does this every other day on grass, if that runner switches from grass to concrete, he or she should reduce the running speed and time.

Any pain or joint stiffness is a warning that the runner is increasing the other elements too quickly, and further cutbacks should be made.

Anatomical Factors

One of the most common reasons why some athletes sustain overuse injuries while others do not is that they have anatomical abnormalities that place additional stress on the surrounding structures. In daily activities, these anatomical abnormalities do not cause problems, but when they are subjected to the repetitive stress of running, overuse injuries may occur. The most common anatomical abnormalities of the lower body are flat feet, high arches, knock-knees, bowlegs, unequal leg length, and turned-in hips (*femoral anteversion*).

Anatomical abnormalities may be difficult to overcome. For example, runners who lack rotation in the hips, particularly internal rotation, may never be able to run without a repetitive pattern of injuries. These participants may have to take up a fitness activity other than running.

A runner who has an anatomical abnormality or suspects that there might be one should consult a sports orthopedist as soon as he or she develops a sport ache.

To realign the lower body and prevent the anatomical abnormality from creating problems, the orthopedist's most frequent course of action is to prescribe either shoe inserts (orthotics) or an exercise program.

Although orthotics are often prescribed to correct high arches, they are frequently ineffective. Sometimes "static stretching" of the arch is of some assistance in alleviating the problem. The runner should stand on a board inclined at an angle of 35° for 20 to 30 seconds at a time, with the toes first facing downward, then upward (when doing these static stretches, the toes should be pointed inward slightly). If the pain continues, the runner may not have any choice other than to take up a different sport.

Runners with bowlegs are susceptible to iliotibial band friction syndrome—inflammation of the tissue on the outer side of the knee. Bowlegs cause the iliotibial band to stretch over a longer distance, making it tighter over the outer side of the knee joint, where symptoms develop. To prevent this condition, runners with bowed legs should take care to stretch the iliotibial band during their prerunning stretch.

Conditioning (Including Muscle Imbalances)

A person whose sole form of exercise is running is often poorly conditioned with respect to the relative strength and flexibility of his or her muscles. That is because when running is done exclusively, it can cause imbalances in muscle strength and flexibility.

The consequence of these imbalances is threefold. First, they can cause stresses to the underlying tissues; second, they can pull certain parts of the anatomy out of alignment; and third, they may interfere with proper running form. All three can lead to overuse injuries.

Stresses Caused by Muscle Imbalances

Tight muscles may be responsible for any number of overuse running injuries. Excessive tightness in the musculature on the outside of the thigh (iliotibial band) can cause pressure on the underlying structures, leading to overuse injuries around the outer side of the knee *(iliotibial band friction syndrome*) and the outer side of the hip (*trochanteric bursitis*). Tight muscles and tendons in the back of the lower leg (gastro-soleus/Achilles tendon unit) can cause *Achilles tendinitis*, inflammation of the thick cord of tissue that connects the calf muscles to the back of the heel, and *plantar fasciitis*, inflammation of the connective tissue underneath the foot that connects the toes to the heel (plantar fascia).

Malalignments Caused by Muscle Imbalances

The most frequent sites of malalignments caused by muscle imbalances are the back and the knee.

Low back pain is common in runners. Often, it is caused by tightness in the muscles in front of the hip (psoas) and behind the thigh (hamstrings) relative to the stomach muscles (abdominals) and the muscles in the front of the thigh (quadriceps). Such an imbalance can cause a postural abnormality called "swayback" or *lordosis*, in which there is an excessive front-to-back curve in the lower spine.

Kneecap pain is another frequent complaint in runners. The most common kneecap problem is patellofemoral pain syndrome, which is usually caused by the kneecap (patella) tracking improperly in its groove at the front of the bottom of the thighbone. Often, this problem is caused by the tightness and strength of the muscles in the back of the thigh (hamstrings) relative to the muscles in the front of the thigh (quadriceps). In such circumstances, the quadriceps cannot maintain the proper straight-ahead alignment of the lower and upper leg when the person runs; as a result, the lower leg "spins out" during the running cycle, which in turn causes excessive stress to the outer side of the kneecap.

The strength ratio between the quadriceps and hamstrings can be measured using the type of strength training machines found in the gyms of most health clubs. The "leg extension" machine measures the strength of the quadriceps; the "leg curl" machine measures the strength of the hamstrings. The strength differential ratio between the quadriceps and hamstrings should be no less than 3:2 in favor of the quadriceps, or problems may occur. In other words, a runner who can lift 80 pounds (lb) with his or her hamstrings using the leg curl machine should be able to lift at least 120 lb with his or her quadriceps using the leg extension machine.

Yet another muscle imbalance–related cause of kneecap pain concerns an imbalance between the muscles in the inner and outer sides of the quadriceps muscles in the front of the thigh, the vastus medialis and vastus lateralis, respectively. Frequently, the outer thigh muscles are tighter and stronger than the ones on the inner thigh. Because these muscles attach to either side of the kneecap, the tighter and stronger outer thigh muscles can cause the kneecap to be pulled to the outside with each step when running, a tracking problem that may in turn result in chronic kneecap pain.

Foot-Strike Problems Caused by Muscle Imbalances

The third problem associated with muscle imbalances is their effect on running form. Running causes tightness in certain areas, notably the psoas muscles in the front of the hip, the hamstring muscles in the back of the thigh, and the gastro-soleus/Achilles tendon unit in the back of the lower leg.

Runners with this pattern of tightness tend to have a much briefer than normal foot strike because their muscles are so tight that they cannot perform the optimal, relaxed heel-to-toe foot strike. Their feet spend much less time on the ground with each step, meaning that they have to absorb much more stress every time they hit the ground. Although the time differential may seem very minor, when one considers that the runner may take 10,000 steps every hour, the consequences may be dramatic.

If the runner is diagnosed with an imbalance in strength and\or flexibility, he or she should participate in a conditioning program to redress that imbalance. Conditioning also encompasses sport ache prevention exercises that need to be done before and after running sessions.

One of the most common reasons why athletes get injured is because they do not prepare their bodies for the demands of exercise with a structured workout that includes warm-up and cooldown periods. Every running session should include five stages: (1) limbering up (5 minutes), (2) stretching (5–10 minutes), (3) warm-up (5 minutes), (4) the run, and (5) cooling-down and cooldown stretching (10 minutes).

Technique

Running would seem to be an elementary activity learned in childhood, but many people run with a poor technique. This may not cause problems when running short distances in daily activities but may result in overuse injuries when those people participate in distance running.

For instance, runners who land excessively hard on their heels may develop a sport ache in their foot. Conversely, those who run on their tiptoes can develop tightness in the calf muscles and Achilles tendons, with the resulting problems.

The following are some general guidelines on running technique:

- Run in an upright position, avoiding excessive forward lean. Keep the back as straight as is comfortable, and keep the head up. Do not look downward at your feet.
- Carry your arms slightly away from your body, with the elbows bent so that the forearms are roughly parallel to the ground. Occasionally, shake and relax the arms to prevent tightness in the shoulders.

- Land on the heel of the foot, and rock forward to drive off the ball of the foot. If this is difficult, try a more flat-footed style. Running on the balls of the foot will cause the runner to tire quickly and make the legs sore.
- Keep your strides short. Do not force the pace by reaching for extra distance.
- Breathe deeply with your mouth open.

Improper running technique may be associated with the tightness caused by running itself, due to muscle imbalances (see the section Conditioning [Including Muscle Imbalances]). Specifically, runners with characteristic tightness in the psoas muscles in the front of the hip, the hamstring muscles in the back of the thigh, and the gastrosoleus/Achilles tendon unit in the back of the lower leg tend to have a much briefer than normal foot strike because the muscles are so tight that they cannot perform the optimal, relaxed heel-to-toe foot strike. Their feet spend much less time on the ground with each step than they should spend, meaning that they have to absorb much more stress every time they hit the ground. To restore proper running form, athletes with tightness in the previously mentioned muscle groups should engage in a flexibility program.

Equipment

Runners exert with each step a combined force of three to four times their body weight. That force is absorbed by the running surface, the shoe, and the foot and leg. The less force the limb absorbs, the less risk there is of overuse injury. That explains why it is better to train on slightly softer surfaces, such as clay or grass, than on cement or asphalt, which has less "give." It also explains why shoes are the most important item in the wardrobe of most athletes.

Shoes are especially important for runners. The right footwear makes for an enjoyable, injury-free running experience, while the wrong footwear can cause discomfort and ailments ranging from ankle sprains to heel spurs to knee cartilage tears. Thankfully, improvements in the past decade have contributed to a decline in many footwear-related overuse injuries. Still, knowing how to select the right footwear is knowledge all runners need to have.

It is especially important for the runner with an atypical foot type to select an appropriate running shoe. For instance, if the runner overly pronates (the foot rolls inward) when running, he or she is susceptible to kneecap pain, iliotibial band syndrome, and tendinitis. That runner therefore needs a shoe that will help minimize that pronation. If the runner's foot excessively supinates (rolls outward) while running, he or she needs an entirely different type of shoe to avoid the characteristic foot, shin, and kneecap pain seen in runners with that foot type.

When Is Self-Care Not Appropriate for a Complaint?

If ever in doubt about the symptoms or proper care of an injury or if self-care measures fail to improve the condition within a reasonable amount of time (2–4 weeks), the athlete should consult a doctor. It may also be necessary to see a doctor if an overuse injury has been allowed to become severe or when symptoms include the following:

- Pain before, during, and after running
- Performance affected by pain
- Normal movement affected by pain
- Pain when pressure is applied to an area
- Swelling
- Discoloration

Common Overuse Injuries in Running

If a sport ache is not addressed, it will usually develop into a full-blown overuse injury. The following are the most common overuse injuries seen in runners.

Foot Overuse Injuries

- *Stress fractures in the foot/heel bones:* A series of microfractures that develop in one or more of the bones in the foot, usually the long bones of the midfoot
- *Morton neuroma:* A nerve inflammation in the foot caused by the nerve being pinched between the third and fourth toes or, less often, the second and third toes
- *Plantar fasciitis/heel spurs:* Inflammation of the plantar fascia where it attaches to the heel bone, which if allowed to worsen may form a bone spur

- *Bunions:* A deformity of the big toe that causes it to angle outward by more than 10° to 15°, so that the tip of the toe points toward the smaller toes (a bunionette is the same condition, but it affects the little toe)
- *Hammertoe:* A buckling-under of the end of the second toe, which may eventually become permanent

Ankle Overuse Injuries

- *Osteochondritis dissecans of the ankle:* Damage to the joint surface, which if allowed to worsen may lead to chips of bone and cartilage falling into the joint
- *Peroneal tendinitis:* Inflammation of the tendon that runs behind the outer ankle bone

Lower Leg Overuse Injuries

- *Achilles tendinitis:* Inflammation of the thick tendon that connects the calf muscles to the heel
- *Medial tibial pain syndrome:* Inflammation of the membrane (periosteum) that covers the shinbone (tibia)
- *Stress fractures of one or both of the shinbones:* A series of microfractures in the lower leg caused by repetitive, low-intensity stress
- *Compartment syndrome:* An overswelling of the muscles in their membranous encasements—an effect that compresses the muscles and nerves within these compartments, causing tightness, numbness, and muscle weakness

Knee Overuse Injuries

- *Iliotibial band syndrome:* Inflammation of the iliotibial band where it rubs against the outer part of the knee joint
- *Osteochondritis dissecans of the knee:* A small divot in the surface of the knee joint, which may eventually break off and fall into the joint
- *Kneecap pain syndrome:* A variety of disorders centering on the kneecap

Hip, Pelvis, and Groin Overuse Injuries

- *Osteitis pubis:* Inflammation of the disk of cartilage (symphysis) that connects the right and left parts of the pubic bone
- *Stress fractures at the top of the thighbone*: A series of tiny cracks in the thighbone just below the ball of the hip joint
- *Trochanteric bursitis:* Inflammation of the bursa sac that lies over the hip joint

Back Overuse Injuries

- *Mechanical low back pain:* Vague pain and stiffness in the lower back, sometimes accompanied by muscle spasm
- *Slipped disk/herniated disk/ruptured disk:* Degeneration in the lower back disks that causes pressure on the nerves

Structure the Workout Properly

Without proper preparation for the physical demands of running, runners are at a greatly increased risk of developing an overuse injury.

Every running session should include 5 minutes of limbering up, 5 to 10 minutes of stretching, 5 minutes of warm-up, and, after the run, 10 minutes of cooldown and cooldown stretching.

Limbering Up (5 minutes)

Muscles must be warmed up before they can be safely and effectively stretched for a run. Raising the body temperature makes the muscles more lubricated and elastic. As body temperature rises, joints increase their secretions, and so there is less friction. Ideal limbering-up exercises include a light jog, riding a stationary bike, a brisk walk, rope skipping, use of a rowing machine, and use of stair-climbing machines.

It isn't necessary to get tired during the limbering-up phase. The limbering-up stage is complete when the runner breaks into a sweat.

Stretching (5–10 minutes)

Five to 10 minutes of stretching exercises should be done after the limbering-up period. Particular attention should be paid to the lower extremities. Remember not to overstretch and to hold each stretch for between 30 and 60 seconds. Do each stretch between one and three times, depending on preexisting levels of flexibility, area-specific tightness and previous injuries, and the chosen sport or fitness activity.

Warm-Up (5 minutes)

The warm-up should ideally last 10 minutes. An effective warm-up for a runner is to perform a walk-jog, then slowly increase it to a run. When warming up for running, the heart rate should be 50% of the maximum heart rate.

Cooling Down (5 minutes) and Cooldown Stretches (5 minutes)

Ending a long run suddenly can cause light-headedness or even fainting. A 5-minute cooling down period helps avoid sudden changes that can cause such problems.

The purpose of the cooldown is to let the heart rate return to normal. Toward the end of the run, runners should gradually slow down to where they are walking. If engaged in competition, continue to walk briskly after reaching the finishing line.

Stretching is also a part of the cooldown period. Stretching for 5 minutes after a run prevents muscles from tightening too quickly. It lessens muscle discomfort and can help maintain general flexibility.

Although most runners recognize the need for a properly structured workout session, many neglect this crucial aspect of preventive sports care. As a result, many get injured. In this fast-paced world, it is difficult enough to find time to exercise, let alone the time for pre- and postexercise workout regimens. But it is absolutely crucial for a person who is going to participate in vigorous exercise to structure his or her workout properly. From an injury standpoint, no exercise session at all is better than a poorly organized one.

Lyle J. Micheli

See also Achilles Tendinitis; Ankle, Osteochondritis Dissecans of the; Athletic Shoe Selection; Bowlegs (Genu Varum); Bunions; Compartment Syndrome, Anterior; Flat Feet (Pes Planus); Hammertoe; High Arches (Pes Cavus); Iliotibial Band Syndrome; Knee, Osteochondritis Dissecans of the; Kneecap, Subluxating; Knock-Knees (Genu Valgum); Lower Back Injuries and Low Back Pain; Medial Tibial Stress Syndrome; Morton Neuroma; Osteitis Pubis; Peroneal Tendinitis; Plantar Fasciitis and Heel Spurs; Slipped Disk; Trochanteric Bursitis

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Sacroiliac Pain

As the link between the spine and the lower extremities, the sacroiliac (SI) joint plays a prominent role in both acute and chronic low back pain. Low back pain is a common problem in both the general population and in athletes. Due to its complex anatomy and biomechanics, the SI joint can be a difficult clinical entity to accurately diagnose and treat. A thorough understanding of its anatomy and functional biomechanics is required to appropriately manage the patient with low back pain due to SI joint dysfunction.

The approach to the athlete with low back pain starts with an accurate and thorough history and physical examination, with special attention to the mechanism of injury and careful palpatory and functional clinical examination techniques. A comprehensive treatment program is required, including functional core and abdominal strengthening, improving lower extremity flexibility, manual medicine, and possibly medications. Other complementary techniques, such as prolotherapy, SI joint injections, and acupuncture may provide benefits but are less well researched.

Anatomy

The region surrounding the SI joint consists of three bony structures: the sacrum, the pelvis, and the lumbar vertebrae. Connecting these structures and providing its movement and function are several muscles, tendons, and ligaments. For example, the sacrotuberous ligament is a fibrous tissue that connects and stabilizes the sacrum and the ischial tuberosity of the pelvis. Its site of attachment on the ischial tuberosity is shared with the long head of the biceps femoris, one of the three components of the hamstring muscle group. The importance of this anatomical relationship is that tight hamstring muscles will often lead to low back pain due to a strain on the sacrotuberous ligament and into the SI joint. Overlying this ligamentous sling is the thoracolumbar fascia, which is a sheet of connective tissue that provides attachment points for multiple major muscle groups of the spine, abdomen, and upper and lower extremities (Figure 1). The breakdown and degeneration of these soft tissue structures often leads to instability in the region, which in turn promotes chronic pain syndromes.

The adult SI joint is a synovial joint, meaning that it is encased in a joint capsule that helps maintain its balance and integrity. The bony structure is described as an L-shaped articulation with a long (upper) vertical pole and a short (lower) horizontal pole. It has also been described as an S- or a C-shaped articulation. There is much variability in SI joint size, shape, and contour, even within the same person. As the population ages, the SI joint develops different elevations and depressions within the cavity in response to repetitive stresses. Due to its role in the transfer of forces between the torso and the lower extremities, the SI joint endures demanding biomechanical loads during sports activities. As a result of these repetitive forces, the joint capsule thickens, and the underlying bone can be eroded, ultimately resulting in arthritic changes.

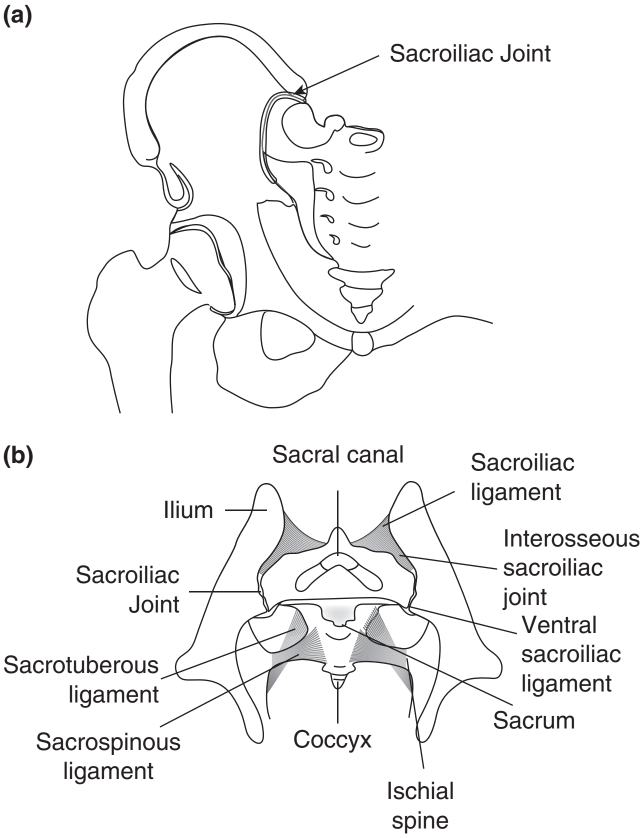

Figure 1 (a) Sacroiliac Joint and (b) Coronal Section of Sacroiliac Joint and Surroundings, Showing Ligamentous Attachments

Although it was previously thought that there is very little motion in the SI joint, most clinicians now accept that there is motion in it throughout life. The hormones released during pregnancy and the increased weight of the baby result in a significant increase in the motion at the SI joint during pregnancy. This is a common reason for low back pain during pregnancy. Further studies and observations have demonstrated that asymmetrical patterns of motion at the SI joints also lead to movement at the pubic symphysis, which is the point where the two pelvic bones meet in the front. Pubic symphysis asymmetry can lead to groin and pelvic pain.

Motion at the SI joint during the normal gait cycle occurs as combined activities in opposite directions at the right and left pelvic bones. At heel strike when stepping forward with the right foot, the right pelvic bone rotates backward and the left pelvic bone rotates frontward. While this is happening, the front surface of the sacrum turns toward the left, the top surface of the sacrum levels off, and the spine straightens upward, slightly turning to the left. Moving toward the right foot midstance, the right pelvic bone rotates frontward, and the sacrum rotates right, while the lumbar spine rotates to the left. The process is repeated in the opposite direction as the left foot approaches heel strike.

Diagnosis

The approach to diagnosis is based on several components, including the subjective complaint of pain, as well as a functional biomechanical examination and the clinician's palpatory findings. There are several SI joint screening tests commonly used. When these tests are used in combination with a thorough history, careful examination, and appropriate diagnostic imaging, an accurate diagnosis and treatment regimen can be established.

The differential diagnosis is broad and can include a number of orthopedic, soft tissue, and visceral conditions that may refer pain to the low back and sacral regions. Some important diagnoses to consider are infections and inflammatory conditions such as arthritis, tumors, fractures, pregnancy, vascular conditions, and hip problems.

When the history and physical examination do not completely uncover the cause of the low back pain, one should consider performing standard radiographs of the lumbosacral spine and pelvis. It is important to obtain oblique views to fully assess the SI joint. If the diagnosis remains elusive or the athlete is not responding to treatment as expected, a further diagnostic workup may include a bone scan, computed tomography (CT) scan, or magnetic resonance imaging (MRI) scan. Laboratory studies may be necessary to rule out infectious or metabolic conditions.

Treatment

Once the diagnosis has been made, treatment generally includes analgesic and/or anti-inflammatory medications. Physical therapy targeting core strengthening and a functional therapeutic exercise program for the lower extremities and pelvis should be initiated. It is important that the demands of the athlete's sport be carefully considered in the design of the rehabilitative program. Using sport-specific concepts in the functional treatment program allows one to reintroduce the loads and motions of a sport in a controlled clinical fashion. Hands-on treatments, including massages, Rolfing, and various manipulative approaches, have been used with varying degrees of success. Finally, injection therapy with local anesthetics, cortisone, and/or prolotherapy can be of benefit, especially in refractory cases. It is important to match the diagnosis with the most appropriate treatment protocol.

Per Gunnar Brolinson and Greg Beato

See also Anatomy and Sports Medicine; Back Injuries, Surgery for; Lower Back Injuries and Low Back Pain

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Sailing and Yacht Racing, Injuries in

Sailing and yacht racing is a long-standing competitive sport. The America's Cup, first won in 1851, is the oldest active international sports trophy. The few studies that document medical concerns of sailing involve highly experienced sailors. Injuries and illnesses occur with similar frequency to other noncontact sports. These concerns are mostly minor, yet some are life threatening. The tendency for injury increases as the wind velocity rises. Medical concerns differ in dinghy and large-boat sailing. Further differences are seen based on boat class, kind of race, level of experience, and crew position. Disabled sailors have injury patterns similar to those of able-bodied sailors. Yacht racing is generally considered a safe sport; however, sailors, governing bodies, boat designers, and sports medicine personnel need to be aware of the associated risks.

Dinghy

Dinghies range in length from 2 to 6 meters (m) and are typically sailed by one to three people. Racing may include multiple short, back-to-back races or one long course. To keep a boat from turning over and to enhance forward momentum, it is important to keep the hull of the boat relatively flat against the water. This is accomplished by *hiking*, the action of leaning much of one's body weight over the edge of the boat. Hiking is usually from a seated position, with bent or straight knees. Dinghies are often equipped with hiking straps, under which sailors slip their feet and lean out to balance the boat. Hiking causes the most injuries in dinghy sailing. Hiking relies heavily on lower extremity and trunk muscle groups. The forces are translated to the lower back and knee.

Collegiate and Olympic dinghy racers are extremely competitive, and they often round marks close together. Injuries tend to be open wounds, sprains, strains, contusions, or fractures. The most common sites of injury are the lumbar spine, knee, and shoulder. The spine is susceptible to ligamentous, muscle, and disk injuries. Repetitive movements, improper lumbar positions, and weak abdominal muscles contribute to excessive loading.

Poor posture and weak core strength can lead to back and knee pain, body aches, fatigue, reduced strength, and muscle imbalance. Sailors should try to achieve a neutral spine/neck and proper scapula setting, "think tall," and avoid a slumped position. Common knee injuries are ligamentous or meniscal injuries, patellar tendinitis, and patellofemoral pain syndrome. Young women may be at greater risk for knee injuries from hiking due to often internally rotated knees. A proper hiking technique with correct strap placement and foot position limits the torque and imbalanced forces on the knee. Land-based hiking benches are quite useful to work on body positioning and muscle strengthening. The shoulder is at risk for rotator cuff and biceps tendinitis because the sailor is steering, trimming a sail(s), or doing both. In high winds, the loads are larger and necessitate persistent contractions of the shoulder muscles.

Another medical concern of dinghy racing is stress to the cardiovascular system. This system should be assessed when doing a preparticipation evaluation since a sailor's cardiorespiratory demands increase with increasing wind velocities and cardiac output and blood pressure rise significantly during strenuous hiking. Another concern for both genders is that of eating disorders, as some classes have weight limits.

Youth racing is very popular. There are 132,000 registered Optimist boats with sailors between the ages of 8 and 15 years. Most youths are required to wear life jackets when racing, though very few programs mandate children to wear a sports helmet. There is not much written on sailing injuries in this age-group. However, growth spurts are often associated with reduced coordination, which may lead to injuries. This typically occurs for girls between 11 and 13 years and boys between 13 and 15 years.

Large Boat

Large-boat competitions may be held on a single day or multiple days, with one or more races per day, local or offshore, or even around-the-world endurance contests. Radio consult provisions permit racers to discuss medical concerns with other racers or gain medical advice via satellite communication. Seldom is medical evacuation required. Sports medicine concerns in large-boat racing include injury, illness, and, rarely, fatalities.

Many large-boat ocean races have an almost century-long tradition. Two had been relatively free of fatalities until one extreme storm occurred during each of them, resulting in 21 deaths. Man overboard (MOB) and head injuries are the most common causes of death while sailing.

There is a high fatality risk from hypothermia or drowning with MOBs during a storm. Sails need to be expediently doused/changed. Even with a global positioning system (GPS), a boat can get 1 mile (mi; 1 mi = 1.61 kilometers) away in 5 minutes and take 20 minutes to return to the MOB site. The overboard sailor may be at risk for hypothermia, drowning, or near drowning. Even if the sailor is found, it may be technically difficult to retrieve the possibly unconscious sailor.

Head injuries while sailing have caused more than 20 deaths in the past 60 years. A direct blow from a moving boom, spinnaker, or jockey pole is typically responsible and often knocks the athlete overboard. Violent weather puts extra stresses on boat parts, often causing unexpected breakages. Life jackets and harnesses greatly increase survival.

Different crew positions have differing responsibilities and tend to have different patterns of injury. A number of actions in yacht racing are sudden, sporadic, and powerful, such as hoisting a large sail. Others may be repetitive and prolonged, such as long-distance steering. Bowmen, grinders, and helmsmen are particularly at risk for injury.

Many above-deck injuries occur from overuse or direct impacts with boat hardware. Falls on deck or down stairs or hatches or while getting on or off a boat often result in injuries. Below-deck injuries typically result from violent and sudden movements of the boat during rough conditions or from cuts and burns incurred while working in the galley.

A 2006 study of America's Cup sailors by V. J. Neville and colleagues, published in the British *Journal of Sports Medicine,* noted an incidence of 5.7 injuries per 1,000 hours of sailing and off-boat training. Training injuries occurred almost four times more frequently than sailing injuries. Twice as many acute injuries as overuse injuries were seen.

The most common injuries encountered while racing are to the upper extremity (finger, hand, shoulder), head and face, and spine and neck. The types of injury most often seen are abrasions, contusions, burns (thermal, rope, sun), closed fractures, lacerations, ligament sprains, tendinopathies, and head injuries without loss of consciousness. Training injuries include sprains, tendinopathies, and muscle strains.

Illness among racing/training sailors tends to be infrequent and minor. The 2006 study by Neville and colleagues showed a 3.1 incidence of illness per 1,000 sailing and training hours.

Upper respiratory tract infections, seasickness, and gastrointestinal issues are the most common illnesses. Contributing factors are a stressful training routine, close living quarters, rough seas, and contaminated water. Sitting on wet, salty surfaces with infrequent bathing causes dermatologic issues. Insomnia, hypertension, sunburn, headache, and infections are also seen.

Medical Preparation

All yachts should be equipped with a medical kit and a communication system that at least two sailors are trained to use. For long offshore racing, a very high-frequency (VHF), single sideband and a satellite system for voice/e-mail are necessary, in addition to an arrangement with a local hospital or telemedicine company for emergencies. Each yacht should designate a medical officer who has attended a marine medical course. Drills for emergencies such as MOBs should be practiced.

Conclusion

While the incidence of injury and illness remains low in competitive sailing, there is room for prevention. Sports medicine personnel can aid the athlete by advising strength and endurance training, cardiovascular fitness, proper nutrition and hydration, prompt medical attention, and mental and safety preparedness. Further research documenting medical concerns, particularly among young sailors, is needed.

Lizanne Backe Barone

See also Dehydration; Knee Injuries; Lower Back Muscle Strain and Ligament Sprain; Shoulder Injuries; Sunburn and Skin Cancers

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Salt in the Athlete's Diet

Human blood contains sodium chloride (NaCl)—common salt—in solution and, in addition, contains smaller quantities of other ions. Electrolytes such as sodium chloride cannot be stored, nor can they be manufactured in the body. These electrolytes must be obtained from our diet. Sodium and potassium salts are needed in greater quantity than any other electrolyte. Maintaining an equilibrium between the salt loss and dietary intake is vital.

A fluid and electrolyte balance is critical to optimal exercise performance. Many athletes, especially endurance athletes, often do not meet their fluid requirements during exercise. However, successful athletes come close to meeting fluid needs, at the same time accounting for their salt loss. Increasing ambient temperature and humidity can increase the rate of sweating on average to 1 liter (L)/hour. Depending on the individual, exercise type, and exercise intensity, sweat rates can range from extremely low values to more than 3 L/hour. Overhydrating with a low or negligible sodium intake can result in reduced performance and hyponatremia. Adding salt to the sports drink actually promotes better absorption in the gut. Sodium also becomes important in the recovery period.

The minimum amount of urinary sodium lost in a day is between 4 and 6 grams (g). This does not include the amount of salt lost in sweat. A dietary intake of 5 to 10 g of salt/day or 2 to 3 kilograms (kg)/year is necessary to maintain homeostasis.

Athletes have varying degrees of salt concentration in their sweat. Those with high salt concentrations may need more salt than the average sweating athlete.

Salt consists of sodium and chloride ions, which are important for normal physiologic functioning. High sweat rates in athletes result in the loss of both fluids and sodium. Fluid replacement with hypotonic solutions such as water will lead to incomplete rehydration and possible complications such as hyponatremia, decreased performance, and heat-related illnesses. There is significant individual variation in the sodium lost during activity. In some, the losses can be replaced by the normal dietary intake, whereas in others, the losses can be so dramatic that extra salt needs to be added to the diet. There are various methods to raise the sodium intake, such as increased use of table salt on foods, eating salty snacks, adding salt to sports drinks, and the use of salt tablets. The emphasis on fluid replacement is also important, but care must be taken to avoid overhydration. Simple measures such as recording the daily pre- and postexercise body weight aid in making fluid and sodium ingestion decisions.

Sweat has an average sodium concentration of 10 to 100 millimoles (mmol)/L. The sweat rate, the amount of fluid lost in 1 hour, can be as high as 3 L/hour. Insufficient substitution can lead to cramps and, as noted earlier, hyponatremia. This is particularly true in hot, humid weather. Athletes can lose up to 5 g of sodium/hour. This can cause a negative balance in the total exchangeable sodium of 30%.

Researchers at the Cleveland Clinic have developed a formula to estimate an athlete's salt loss:

$$\text{Salt loss} = 0.0263 \times \text{Sweat [Na]} \times \text{Weight loss.}$$

As mentioned earlier, the sweat sodium concentration can range between 10 and 100 mmol/L. For simplification purposes in this example, the sweat concentration is set at 50 mmol/L. For individualized calculations, the specific salt concentration of the athlete's sweat should be used.

Example: If a player loses 10 pounds (lb; 1 lb = 0.45 kg) during practice with a sweat sodium concentration of 50 mmol/L, he or she will have lost $0.0263 \times 50 \times 10 = 13.15$ g of salt.

The use of sports drinks has increased dramatically in recent years. How much do these sport drinks actually help in stabilizing the sodium balance?

Modifying the preceding formula, the sodium salt content of a beverage can be assessed as follows:

$$\text{NaCl (g)} = 0.00252 \times \text{[Na] (milligrams [mg]/vol)} \times \text{vol.}$$

A popular beverage targeting athletes has 110 mg of sodium in 8 ounces (oz; 1 oz = 29.57 milliliters [ml]). If an athlete drinks one 20-oz bottle of it, he or she will have consumed

$$0.00252 \times 110/8 \times 20 = 0.693 \text{ g of salt.}$$

In the example above, the athlete lost 13.15 g of salt. To replace that by just drinking the sports drink (second example), he would have to drink nineteen 20-oz bottles!

An average diet contains between 8 and 10 g of salt. Thus, much of the sodium lost in an event will be replenished by regular dietary intake. If, though, an athlete has a weight loss of 5 lb or more during an athletic event, a salt substitution should be considered. A basic rule would be to supply 1 g of salt and 500 ml (=16 oz of fluid) for each pound of weight loss over 5 lb.

Marc P. Hilgers

See also Dietitian/Sports Nutritionist; Fat in the Athlete's Diet; Nutrition and Hydration; Sports Drinks

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Scaphoid Fracture

The *scaphoid* is one of the small bones of the wrist. It is the most frequently fractured carpal bone, accounting for 71% of all carpal bone fractures. The incidence of fracture is greater in young and middle-aged men, typically those between 15 and 60 years.

Many cases of painful wrists due to a fractured scaphoid are seen in the emergency department. Early diagnosis is important as 90% of all acute scaphoid fractures heal if treated early. On the other hand, a delay in diagnosis can lead to a variety of adverse outcomes.

Anatomy

The wrist is made up of eight carpal bones, which are arranged in two rows (Figure 1). The scaphoid is the most lateral bone of the proximal row. It articulates with the radius superiorly.

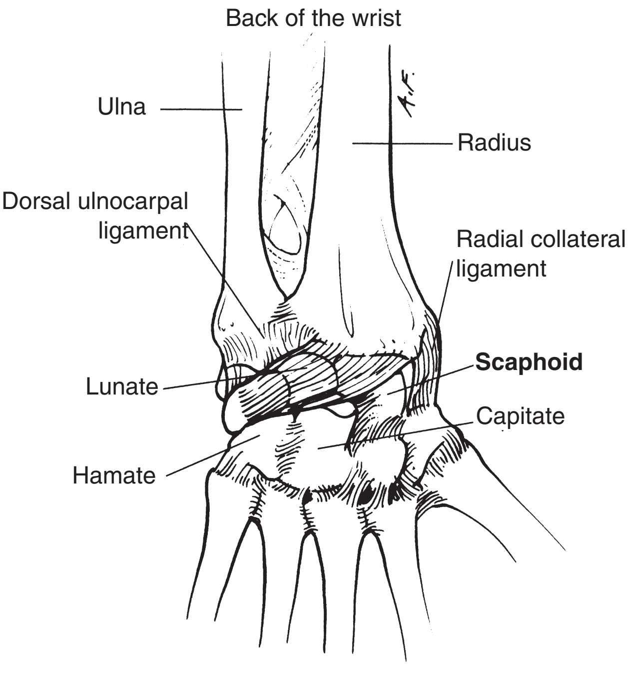

Figure 1 Anatomy of the Wrist

On surface anatomy, it is located below the anatomic snuffbox—a triangular depression lying below the thumb, best visible when the thumb is extended. This boat-shaped bone is key to wrist motion and stability. It can be divided into four distinct parts: the proximal pole, the wrist, the distal body, and the tuberosity. Most scaphoid fractures occur at the waist and the proximal pole.

The scaphoid is supplied by the radial artery near the tubercle and waist. The blood supply to this bone is paradoxical, going from distal to proximal. Thus, fractures in this part heal slowly, and the bone fragments may even fail to fuse.

Causes

Most patients who have broken their scaphoid have done it while participating in sports such as football or basketball; two-wheeled sports such as motocross, bicycle motocross (BMX), and cycling; or in an automobile accident. It usually happens from a fall on an outstretched hand (FOOSH) with the wrist pronated (palm facing backward).

Symptoms

A fracture of the scaphoid almost never shows any obvious deformity of the wrist. Symptoms of a fracture include pain at the base of the thumb and a swelling around the wrist. Loss of the concavity of the anatomic snuffbox is usually seen.

Pain may subside and then return as a deep, dull ache that may worsen when the thumb is moved or the hand grips an object. In some cases, the pain is not severe and may be mistaken for a sprain.

Clinical Evaluation

Physical Examination

The age and sex of the patient are considered together with the mechanism of injury. It is important to compare the injured wrist with the uninjured wrist.

The following observations on performing specific maneuvers suggest a fracture of the scaphoid:

- There is tenderness on palpation at the anatomical snuffbox.
- The scaphoid tubercle is tender. Extend the patient's wrist with one hand, and apply

pressure on the tuberosity at the proximal wrist crease with the other.

- Absence of tenderness on performing the first two examinations makes a scaphoid fracture highly unlikely.
- There is pain on performing the "scaphoid compression test." This test involves longitudinally compressing the patient's thumb along the line of the first metacarpal.
- Pain is felt on pronation followed by ulnar deviation.
- There is reduced range of motion of the hand.

Imaging

There are various imaging options to figure out the fracture in a patient with a suspected scaphoid injury:

- *Radiography:* Anteroposterior, lateral, and oblique radiographic views of the wrist are required. A special radiograph called a scaphoid view is also recorded occasionally. Nondisplaced fractures (fractures in which the bone fragments have not been displaced) are usually not seen on initial radiographs.
- *Bone scintigraphy:* It is a cost-effective and accurate method for assessing occult scaphoid fractures.
- *Magnetic resonance imaging:* It is a highly sensitive, noninvasive modality that can not only detect occult scaphoid fractures but can also access bone healing and evaluate for bone contusions and ligamentous injuries.
- *Ultrasonography:* Ultrasound examination is not appropriate in the initial evaluation of a suspected scaphoid fracture. Nevertheless, it is reliable and accurate in identifying occult scaphoid fractures.

Treatment

Nonsurgical Treatment

Scaphoid fractures are usually not visible on X-rays immediately after an injury. A wrist injury suspected of a scaphoid fracture by examination should be casted, with follow-up examination done in 7 to 14 days. However, it is possible that the fracture line is still not visible; in such cases, an MRI or CT scan may be necessary to confirm the diagnosis.

In a fracture where bone is not displaced (bone fragments are in the right place) and/or fractures that do not extend across the bone's length, simple treatment with cast immobilization may heal the fracture within 9 to 12 weeks; inclusion of the thumb in the cast is usually recommended. Recovery is monitored by examining plain radiographs. If the fracture does not heal, surgery is recommended.

Surgical Treatment

Surgery is indicated in the following situations:

- When the bone is displaced (fragments are not in their anatomical position) and is hence at a higher risk of nonunion (failure of bone to heal)
- When the athlete is anxious to return to play as soon as possible (Surgery allows the patient to get early mobilization and complete functionality in a shorter duration. This reduced time spent in a cast also helps reduce muscle atrophy.)
- When the scaphoid fracture is undiagnosed initially, with nonhealing (nonunion)
- In a nondisplaced fracture when healing does not occur in a timely manner with cast immobilization
- When the fracture is in the middle or proximal part (nearer the forearm), since it may not heal with only the cast because of the reduced blood supply in this part of the bone

Two surgical options are available: (1) open reduction and internal fixation and (2) closed reduction and percutaneous fixation. The former is for displaced fractures, whereas the latter is for fractures that have minimal displacement. In the surgical method, cannulated screws or wires are used to stabilize the fragments. The length of the incision and the area where it is placed depend on the degree of displacement of the fragments and the part of the scaphoid that is fractured. It can be on the front or back of the wrist. The incision is larger when fragments have to be realigned into their anatomical position before they are stabilized with screws. Postoperatively, the hand is placed in a cast and regularly monitored with radiographs to check the progress of the healing process. The bone heals within 8 to 12 weeks.

Even with surgery, this fracture takes time to heal or may not heal properly. If the bone does not heal, a bone graft is added in addition to internal fixation. (The grafts are usually taken from the patient's pelvis.) During this process, the hand is placed in a cast. Bone grafts speed up the healing process, and the cast is usually removed in 3 weeks, allowing rehabilitation exercises of the hand and wrist. Also, in fractures where the blood supply has been severed, special grafts, called vascularized grafts, are used that have their own blood supply.

Complications

The proper treatment of scaphoid fractures is extremely important. If the bone fails to heal, it is called a *nonunion*. One cause of nonunions, as noted earlier, is the poor blood supply to the fractured part, which results in bone death. This is referred to as *avascular necrosis*. Nonunion and avascular necrosis subsequently lead to arthritis of the wrist, resulting in pain and a reduced range of motion; the person experiences difficulties in performing even normal activities such as lifting and gripping.

Rehabilitation

Cast immobilization and functional disuse can lead to swelling (edema) of the injured wrist. Elevation and active motion of the uninjured joints of the hand can help avoid this fluid accumulation. During the healing period, the patient must avoid any strenuous activity with the injured arm, including lifting, pushing, pulling, and throwing. Participation in contact sports must be avoided, and care must be taken to avoid activities that increase the risk of falling onto the hand.

After the cast is removed, active range-of-motion (ROM) exercises for wrist flexion and extension and radial and ulnar deviation are performed to overcome the stiffness. About 2 weeks later, passive range-of-motion (PROM) exercises are started, together with gentle muscle-strengthening exercises. Progressive strengthening over several weeks by means of weight bearing and other activities will help restore complete functionality to the wrist.

Hira Bashir and Fatima tuz Zahra

See also Wrist Dislocation; Wrist Fracture; Wrist Injuries; Wrist Sprain; Wrist Tendinopathy

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Scheuermann Kyphosis

When viewed from the side, the human spine has a series of normal curves. The lower back or lumbar spine is curved anteriorly (*lordosis*). The upper back curves outward and is referred to as a *thoracic kyphosis*. This is a C-shaped opening anteriorly. The cervical spine maintains a mild lordosis. When any of these curves are excessive, they can cause pain and cosmetic deformity. The normal thoracic kyphosis is between 20° and 40°. There are several causes of excessive kyphosis. A congenital fusion or abnormality may cause a fixed kyphosis noted early in life. Later in life, osteoporosis may cause an excessive kyphosis, or dowager's hump, due to compression fractures. In the adolescent, there are two causes of noted kyphosis. One is postural, due to slouching and poor spinal extension strength, and is usually correctible with postural strengthening. The second is *Scheuermann kyphosis*.

Scheuermann kyphosis is a developmental fixed deformity of adolescence. By definition, there are at least three consecutive vertebrae involved, with anterior wedging of 5° or more. The prevalence has been estimated to be between 4% and 8% of the population. It is usually recognized during the adolescent growth spurt. When detected with spinal growth remaining, it can be minimized with exercises and bracing. Thus, early recognition is important.

Etiology

There have been a number of theories as to the causes of Scheuermann kyphosis. Genetic factors have been strongly implicated, but there has been no specific genetic marker identified. Some have attributed this to an osteochondrosis, which refers to a loss of blood supply to the growth cartilage rings that are located on the superior and inferior parts of each spinal vertebral body. Repetitive compression of the anterior portion of this ring will inhibit the growth and cause anterior wedging. In keeping with this theory, muscular imbalances with stronger anterior trunk muscles would put excessive pressure on the anterior ring apophysis. Furthermore, it has been noted in industrial workers in excessive forward flexion. There has also been a noted association with elite levels of water skiing in the preadolescent and adolescent age-groups. Other possible etiologies include transient osteoporosis and growth hormone imbalance.

With regard to gender, some studies have indicated that there is a male predominance, while others have shown a more equal, 1:1, ratio.

Clinical Presentation

The most common presentation is a cosmetic deformity noted by parents during the adolescent growth period. It is a very gradual development that is usually painless. Parents often consider this to be postural. About 25% of these adolescents have an associated scoliosis of less than 25° to 30°. Scoliosis is a lateral curvature of the spine. Kyphosis is best detected on forward flexion, viewed from the side (see photo, right column). Scoliosis is also seen on this forward flexion test but viewed from behind. Scoliosis will manifest with an asymmetry of the rib humps in flexion. When a kyphosis is detected, one should determine if it is fixed or postural. When the patient extends backward or is prone while suspended on the elbows, the postural kyphosis is corrected, while the Scheuermann kyphosis remains.

One of the significant problems of excessive kyphosis is loss of self-esteem. The kyphosis may cause a cosmetic deformity and make the individual appear heavier. Although the adolescent may complain of pain at the apex of the deformity, it is more common for an adult to complain of pain. It is likely that in the adult, the local degenerative processes of the disk and posterior spinal elements are causing focal irritation. The increased thoracic kyphosis alters the biomechanics of the lumbar spine, with increased lordosis to compensate. This excessive lordosis may cause stress in the posterior elements of the lumbar spine with a spondylolysis (stress fracture). Although quite uncommon, neurologic compression may also occur with peripheral manifestations. These may include pain radiation to the chest wall, to the abdominal wall, or into the legs.

Kyphosis. Patient is in forward flexion, viewed from the side.

Source: Photo courtesy of Pierre A. d'Hemecourt.

Imaging

The standard evaluation of a suspected kyphosis includes a standing series of the thoracolumbar spine, which involves posteroanterior (PA) and lateral views. The PA view will detect any scoliosis. The lateral view is useful for determining the amount of kyphosis using the Cobb method (Figure see radiograph, next page). This measures the angle from the superiormost vertebrae to the inferiormost vertebrae. To meet the criteria of Scheuermann kyphosis, there must be an overall kyphosis of more than 45°, and at least 5°, with three consecutive wedged vertebrae. A lateral radiograph in extension may be considered if there is a question whether the kyphosis is more postural.

If there is a kyphosis, one must determine bone growth as improvement can only occur in the setting of remaining spinal growth. Therefore, the pelvic portion of the plain PA radiograph will help determine the remaining growth potential by calculating the Risser score of the iliac crest growth cartilage (Figure 1). The iliac apophysis ossification appears laterally to medially. Each 25% is divided into the first four scores. Risser I is the

Kyphosis, plain posteroanterior radiograph

Source: Photo courtesy of Pierre A. d'Hemecourt.

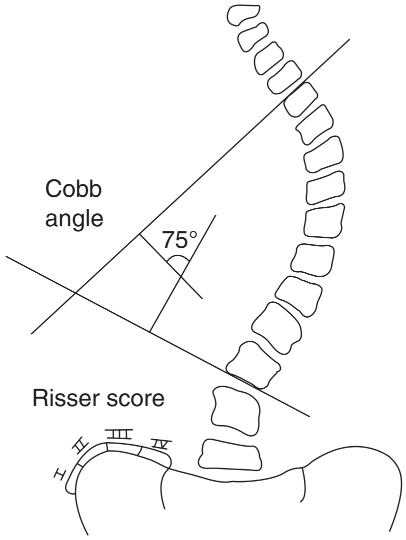

Figure 1 Risser Score

Source: Pierre A. d'Hemecourt.

appearance of the first 25%. Risser II is the first 50%. Spinal growth is most noted up to Risser II. A left hand/wrist radiograph may also be obtained for bone aging.

Further imaging with an MRI scan is useful if there is significant pain. This will demonstrate any significant disk disease as well as spinal cord abnormalities such as a syrinx (cystlike structure).

Treatment

The ideal treatment candidate is the adolescent with significant growth potential and a curve in excess of 45°. Treatment consists of an upper back extension–based strengthening program combined with a core stabilization program. This is an important part of the treatment and is very useful for the postural component. Bracing is also optimal here. Usually, the apex is at T7 or above it and requires a Milwaukee brace. This brace comprises a pelvic girdle, a pad at the curve apex, and a shoulder with a cervical ring fixation. Ideal treatment is at least 18 hours/day for the first year and nighttime wear until skeletal maturity. Radiographs are repeated every 4 to 6 months. This brace is not well tolerated and at times is just used for nighttime wear. When the kyphosis has an apex below T7, a more tolerable thoracolumbarsacral orthosis (TLSO) is used. The TLSO is also continued until skeletal maturity.

Surgical intervention is reserved for those curves in excess of 75°. The Milwaukee brace is ineffective at this degree of curvature. The surgical stabilization usually involves an anterior and posterior approach with fusion with fixation. A posterior-only approach may be followed if there is some flexibility to the curve, but this provides less curve correction than does the combined approach. Complications can include spinal cord injury, nonunion of the fusion, and infection. The results can be very satisfying.

Return-to-Sports Considerations

There is no real restriction to play in most of these athletes unless there has been a surgical fusion with instrumentation. In the latter case, contact sports are a contraindication. In the nonoperatively treated group, sports participation of all kinds is encouraged as long as the principles of sports biomechanics are addressed. In sports that require forward thoracolumbar flexion such as crew and wrestling, the athlete is instructed in upper back extension postures with a good upper back–strengthening program. When bracing is used, the athlete is usually allowed out of the brace for all practice and competition events. This allows better compliance and enhances spinal stabilization.

Pierre A. d'Hemecourt

See also Back Injuries, Surgery for; Lower Back Injuries and Low Back Pain; Musculoskeletal Tests, Spine

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Sciatica

Low back pain affects a significant portion of the population, with epidemiologic studies reporting a lifetime prevalence of 49% to 70%. *Sciatica*, also referred to as *lumbosacral radicular syndrome*, is a type of low back pain that is characterized by pronounced posterior radiating leg pain. The pain follows a distribution served by a lumbar or sacral spinal nerve root and is often accompanied by sensory, motor, or tendon reflex abnormalities. The prevalence of sciatica has been estimated to be around 2% to 10%. This prevalence is likely higher in athletes, especially high-level or elite athletes, due to the increased physical demands placed on the spine during many athletic activities. Clinicians that care for athletes must have a good understanding of the causes, diagnosis, and treatment of sciatica to expedite a safe return to athletic activity.

Anatomy

In the lower back, the lumbar spine is composed of five vertebral bodies. The sacrum, a large triangular bone consisting of five fused vertebrae, connects the lumbar spine and the tailbone or coccyx. The spinal cord traverses through the spinal canal of the vertebrae, and nerves coming off the spinal cord travel through the spinal canal and exit through small openings on the sides of the vertebrae called *foramina* (singular foramen). The sciatic nerve is the largest and longest nerve in the body and originates from a group of nerves in the lower back. It then runs through the buttock and down the lower leg, supplying motor and sensory functions to the thigh, knee, calf, ankle, foot, and toes. Between each of the vertebrae is a vertebral or spinal disk that serves as a shock absorber. Each disk is composed of two parts: (1) an outer tough exterior (annulus fibrosis) that surrounds and contains (2) an inner jelly-like material (nucleus pulposus).

Causes

The leading etiology of sciatica (approximately 90% of cases) is a herniated disk causing nerve root compression. Other etiologies include lumbar stenosis (narrowing of the lumbar spinal canal), facet joint osteoarthritis, spinal cord tumors, and infection. Disk prolapse is more commonly identified as a cause of nerve root compression among younger athletes (20- to 50-year-olds), while osteophytes and degenerative disease are often the culprits in older athletes. The red flags for life-threatening etiologies have been widely recognized, and more aggressive and urgent workup is needed if these are identified (Table 1). Several factors have been shown to increase one's risk for sciatica: age (peak between 45 and 64 years of age), increasing height, mental stress, cigarette smoking, strenuous physical activity, and exposure to vibrations from vehicles.

Clinical Evaluation

History

The first step in managing an athlete with sciatica is to recognize the condition. The physician's

Table 1 Red Flags for Low Back Pain

History or Physical Exam Clue	*Possible Diagnostic Etiology*
Saddle anesthesia	Cauda equina syndrome
Urinary retention	Cauda equina syndrome
Bowel or bladder incontinence	Cauda equina syndrome
Loss of rectal tone	Cauda equina syndrome
Major motor or sensory loss	Cauda equina syndrome, significant herniated disk
History of cancer	Metastatic disease
Age over 50 years	Neoplasm
Unexplained weight loss	Neoplasm
Nighttime pain	Neoplasm or infection
Fevers	Spinal infection
Recent infection (pyelonephritis, cellulitis, etc.)	Spinal infection
Vertebral tenderness	Spinal infection or fracture
Unrelenting pain	Spinal infection, neoplasm, or fracture
Immunosuppression	Spinal infection
Intravenous drug use	Spinal infection
Fall in osteoporotic patient	Vertebral compression fracture
Trauma (motor vehicle accident, fall from a height, etc.) in young patient	Vertebral fracture

Source: Susan Bettcher and James Borchers.

main diagnostic tool is obtaining a thorough history and performing a comprehensive yet focused physical examination. Patients frequently report a shooting, radiating, or burning leg pain that extends to the ankle and foot, often with athletic activity. Pain commonly travels along the lateral and posterior aspects of the thigh and leg. These symptoms are often accompanied by a component of numbness or a tingling sensation. Sciatica pain attributed to disk herniation can increase with maneuvers such as coughing and with running activities.

Physical Exam

The physical exam should include inspection, palpation, and range-of-motion testing of the lower back and legs, along with documentation of vascular integrity. Emphasis should be placed on neurological testing. A key diagnostic tool to help assess for radiculopathy is the *Lasegue sign,* more commonly referred to as the straight leg raise test. For this maneuver, the clinician elevates the supine patient's extended leg without his or her assistance. The test is positive if sciatica is reproduced between 10° and 60° of elevation. A second maneuver is the crossed straight leg raise test. This test focuses on raising the unaffected leg; a positive result occurs if pain is reproduced in the affected leg. A variation of the above tests, the seated straight leg test, is performed with the patient seated. The leg is extended until there is 90° of flexion at the hip. The test is positive if pain is elicited as the leg is raised. If one or more of these maneuvers are positive and the pain description is consistent with sciatica, a diagnosis of sciatica can be made.

Diagnostic Tests

Performing laboratory or imaging studies is often not necessary when diagnosing sciatica as these tests do not affect the typical treatment course, which is conservative management. However, if any red flags are present, further workup should be initiated at the time of diagnosis. In addition, imaging studies are often indicated if the diagnosis is uncertain or if there is a lack of response to conservative management after 6 to 8 weeks. Imaging can be used to help identify the pain source, such as a herniated disk. This information can be used to determine if surgical intervention is indicated. Disk herniations are frequently seen on computed tomography (CT) scans and more commonly on magnetic resonance imaging (MRI) scans. The findings must be correlated to the distribution of symptoms, and a decision must be made as to whether the pattern makes sense. Imaging studies depend on various factors (availability of testing, patient health, cost, etc.) and the physician's preference.

Treatment

The overall prognosis for sciatica is good as a majority of patients and athletes recover from related disabilities within a couple of weeks to months. However, the symptoms can become chronic, and a minority of athletes can continue to have pain for periods greater than 1 year. The mainstay of the treatment is conservative management, which focuses on pain control. However, if there is a lack of clinical improvement after 6 to 8 weeks, surgical intervention can be considered. The effectiveness of certain conservative measures and the optimal timing of surgery still need to be established.

Nonsurgical Treatment

Conservative management involves one or more of the following: patient education, bed rest, remaining active, use of analgesics such as nonsteroidal anti-inflammatory drugs (NSAIDs), epidural steroid injections, physical therapy, spinal manipulation, acupuncture, traction therapy, and behavioral treatment. While there is no solid evidence for the effectiveness of any of these measures, bed rest is no longer recommended because no significant difference in pain and functional status measures has been seen when compared with staying active. As such, physicians recommend that their athletes with sciatica remain active but avoid activities that aggravate their pain. Formal physical therapy is also recommended by certain providers and may be helpful in individuals with more severe pain and/or disability. For athletes with access to training facilities, a certified athletic trainer can guide the rehabilitation and monitor a graduated return to play. Physicians often prescribe NSAIDs for the initial pain associated with sciatica. Other non-NSAID analgesic pain medications, muscle relaxants, and antidepressants may be used instead of or in addition to NSAIDs. A conservative treatment plan should be made in conjunction with the athlete, keeping in mind the current knowledge of treatment modalities, our understanding of the expected course of sciatica, and the athlete's performance goals.

Surgical Treatment

An immediate neurosurgical referral needs to be made for the cauda equina syndrome, which is characterized by saddle anesthesia, decreased rectal tone, and changes in the urination and bowel functions. Urgent referrals should be made if progressive paresis and/or acute severe paresis are present. Other nonurgent referral indications to neurosurgery, neurology, or orthopedic surgery include severe pain in spite of adequate medication, uncertain diagnosis, and lack of clinical improvement after 6 to 8 weeks. Surgical intervention can be undertaken in cases of refractory sciatica in which there is an identifiable source of pain, such as lumbar disk prolapse. Surgery aims at removing the disk herniation through surgical diskectomy or microdiskectomy. There may be an initial improvement in leg pain and faster recovery in individuals treated with early surgery, but the long-term outcomes of surgery have not been shown to be better than those managed conservatively. As such, providers need to discuss the available evidence and knowledge of treatment modalities and outcomes with their affected athletes so that they can make well-informed decisions.

Susan Bettcher and James Borchers

See also Back Injuries in Sports, Surgery for; Cervical and Thoracic Disk Disease; Lower Back Injuries and Low Back Pain; Musculoskeletal Tests, Spine; Slipped Disk

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Scoliosis

Scoliosis is an abnormal curvature of the spine when viewed from the back. In this position, the spine normally appears as a straight line from the occiput to the pelvis. With scoliosis, this may appear as a single C-shaped curve or a double S-shaped curve. There is often an associated rotational component that presents with a rib hump or lumbar prominence, depending on the location of the curve. The overall prevalence of scoliosis is 2% to 3%. However, severe curves occur in less than 0.1% of the population. The prevalence of minor curves is equal between men and women, but more significant curves demonstrating progression are at least five times more common in women.

Scoliosis curves may be described by the location of the apical vertebra. This is the vertebra that is most deviated from the midline. There are 7 cervical vertebrae, 12 thoracic vertebrae, and 5 lumbar vertebrae. The position of the apical vertebra defines the curve level: cervical from C2 to C6, cervicothoracic from C7 to T1, thoracic from T2 to T11, thoracolumbar from T12 to L1, lumbar from L2 to L4, and lumbosacral from L5 to the sacrum. Single or multiple curves may be seen. The curve is further defined by the direction of the convexity (outer portion of the curve). A curve that is convex to the right is called dextroscoliosis; convexity to the left is levoscoliosis. Curves may be single or multiple.

The objective of scoliosis identification is to prevent the progression, which may be associated with functional deformity, cosmetic deformity, and potentially pain in the adult. The young woman athlete is often seen with this on preparticipation examination.

Classification

Scoliosis may be classified according to the etiology. Curves may be secondary to congenital, neuromuscular, and idiopathic causes. Congenital causes usually reflect bony abnormalities, as a result of which one is born with the spinal vertebrae incompletely separated from an adjacent level or incompletely formed. These curves often present early in life.

Neuromuscular scoliosis refers to curves that are secondary to neurologic and muscular disorders. Spinal cord abnormalities such as a syringomyelia (a cystic-like structure in the cord) and a tethered cord may cause an abnormal curvature. Some inherited muscular and neurologic diseases such as muscular dystrophy may present with a gradually progressive curve. Connective tissue abnormalities such as Marfan syndrome and Ehlers-Danlos syndrome also fall in this category. Certain tumors such as neurofibromatosis and osteoid osteomas also represent neuromuscular causes.

At least 80% of scoliosis cases are classified as *idiopathic*, which means that there is no known cause. Idiopathic scoliosis is further subclassified by the age of onset:

- *Infantile, under the age of 3:* Unlike the older idiopathic forms, this is more prevalent in the male population and has a more positive ability to be corrected on its own.

- *Juvenile, between 3 years and 10 years of age:* This has a much higher risk of progression and must be monitored closely. It also has a significant risk of comorbid spinal cord abnormalities that must be considered.
- *Adolescent idiopathic scoliosis, over the age of 10 years:* This is the most common entity and is most often seen in the young woman athlete.

Numerous hypotheses have been postulated regarding the cause of scoliosis. However, it remains unclear. Chromosome mapping has made specific identifications, but there appears to be an incomplete genetic expression. Other factors that have been considered include abnormalities of growth hormone secretion, melatonin secretion, and skeletal muscle contractile protein.

Evaluation

Often, the young athlete presents with a curve that was noted on a routine examination. The history and physical examination should focus on excluding significant causes and determine the risk of progression. This will assist in determining the need for more advanced imaging and testing. It is important to determine at which age it was first noticed for classification. The presence of pain or neurologic complaints is important. The family history of scoliosis should be determined. The highest risk of curve progression occurs during the adolescent growth spurt. This growth spurt precedes the onset of puberty in women, manifested with the onset of menses. Thus, the premenarchal (prior to the first menstrual cycle) woman is at a higher risk of progression. In the male athlete, the onset of puberty, with testicular enlargement and pubic hair development, precedes the growth spurt. Growth in the female athlete continues for up to 2 years after menarche.

The physical examination includes the height. This is important in following the adolescent to determine the cessation of growth. This occurs when there is less than 1 cm of growth in a 6-month time period. The physical examination is performed in the usually disrobed adolescent to look for skin abnormalities, such as café au lait spots, hairy patches, and dimpling, which may indicate underlying cord abnormalities such as neurofibromatosis and spina bifida. One should also examine for connective tissue disorders. The stigmata of Marfan syndrome should be assessed in the tall woman more than 5 feet (ft) 10 inches (1.75 meters [m]) and men more than 6 ft (1.8 m) in height. Tall athletes with two or more of the following major criteria of Marfan syndrome should be referred for genetic testing and echocardiography:

- *Ocular:* lens dislocation, myopia (nearsighted)
- *Cardiovascular:* mitral valve prolapse, aortic rupture
- *Musculoskeletal:* scoliosis, anterior chest wall deformities (pectus excavatum and carinatum), long thin fingers (arachnodactyly), arm span longer than the height, and a high-arched palate.
- Family history of *Marfan syndrome*

A neurologic examination should be complete, looking for abnormal reflexes such as Babinski reflexes (up-going toes with plantar foot stroking) and hyperreflexia. These may indicate a spinal cord abnormality.

The degree of scoliosis is initially evaluated with the evaluator standing behind the patient with the forward-bending test. With this maneuver, the curve becomes more obvious due to the rotational component, which makes the ribs more prominent on the convex side. This is more accurately assessed using the scoliometer. This is placed on the spine in the forward-flexed posture and quantitates the degree of rotation. When the scoliometer reads 7 or more, the patient should have an X-ray to determine the severity of the curve. If one uses a lower number such as 5, the specificity diminishes, and excessive numbers of radiographs are ordered. However, it is important to realize that not all scoliosis cases involve a rotational deformity. Thus, when the spine appears curved even without rotation, a radiograph should be considered.

When indicated, the initial imaging should be a full-length posteroanterior (PA) and lateral spine X-ray including the pelvis. Each curve is identified and quantified using the Cobb method (Figure 1). The top of the curve is determined at the level at which the vertebrae deviate the most from the central axis. The bottom of the curve is determined similarly. A line is drawn across the top of the uppermost vertebra, and one is drawn across the lowermost vertebra. Perpendicular lines to these are made to intersect. The intersection angle determines

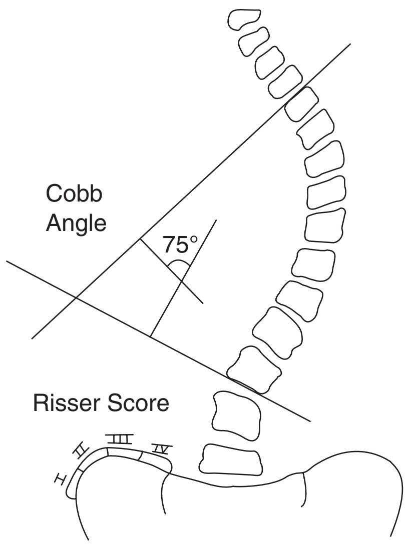

Figure 1 Cobb Angle and Risser Score

Source: Pierre A. d'Hemecourt.

the extent of the curve. The curve must be greater than 10° to be classified as scoliosis. Lesser curves are referred to as spinal asymmetry.

The pelvic portion of the plain PA radiograph helps determine the remaining spinal growth potential by calculating the Risser score of the iliac crest growth cartilage (iliac apophysis). The iliac apophysis ossification appears from lateral to medial. Each 25% is divided into the first four scores. Risser I is the appearance of the first 25%. Risser II is the first 50% (Figure 1). Curves are more likely to progress in the early Risser scores of I or II.

The degree of the curve and the Risser score help determine the risk of progression. Curves less than 20° have a lower risk of progression unless the Risser score is less than I (22% risk of progression). A curve from 20% to 29% has a much higher risk of progression.

Further imaging with an MRI scan is considered when there are findings in the history and physical examination that indicate a neurologic concern as well as head, neck, or spinal pain. This should also be done on patients with juvenile onset and, according to some authorities, on patients with left-sided thoracic curves. The MRI scan should be a spinal screen that looks at the entire spine, including the junction with the occiput, to evaluate for a Chiari malformation (herniation of the cerebellar tonsils into the spinal canal).

Treatment

Observation

In mild curves, measuring less than 20°, observation is appropriate. The timing of this will depend somewhat on the age. Athletes less than 12 years of age or with a Risser score of I or less should be followed every 4 months. Older athletes can be followed every 6 to 8 months with a PA spine X-ray. Curves between 20° and 29° should be monitored more frequently, every 3 to 6 months. A progression of 5° may indicate a need for bracing.

Bracing

Curves that progress more than 5° should be considered for bracing. Curves more than 30° are also braced. Once initiated, the patient should have an initial PA radiograph of the spine in the brace to determine the degree of correction, as a value greater than 20% is a good prognostication for bracing efficacy. Bracing is continued until skeletal maturity, which is usually 1 to 2 years postmenarche.

Bracing may take several forms. The Boston overlapping brace is a commonly used thoracolumbarsacral orthosis (TLSO). It is worn ideally for 23 hours/day but has been used for 16 hours/day.

Rarely, a larger brace, the Milwaukee brace, is used to involve the cervical spine (cervicothoracolumbosacral orthosis [CTLSO]). This is used for high thoracic and double thoracic curves. Compliance is more difficult. There are two nighttime braces, the Charleston and Providence braces. Some studies indicate that they limit the progression of the curves. The data on the efficacy of all bracing are controversial and are being verified by ongoing clinical trials.

Surgical Intervention

Skeletally immature athletes who have a curve in excess of 50° are candidates for surgical stabilization, with consideration of the same for those with curves between 40° and 50°. Those adolescents who progress more than 5° while being managed in the brace are also considered for surgery. The surgical procedure usually involves segmental instrumentation and fusion. Curves that are very rigid may require an anterior thoracoscopic release.

Sports Participation

Sports participation is encouraged at all levels of scoliosis. Although physical therapy has not been shown to be helpful in managing the curve, the athlete should maintain cross-training and core stabilization for normal athletic conditioning. Full sports participation is encouraged. For some sports that emphasize repetitive asymmetrical spinal loading, such as rhythmic gymnastics, athletes are encouraged to cross-train to lessen these forces.

Many sports can be played while wearing a brace. In some sports such as gymnastics and swimming, the brace is removed during athletic competitions. However, if spinal instrumentation is performed, collision sports are contraindicated.

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See also Back Injuries, Surgery for; Cervical and Thoracic Disk Disease; Gymnastics, Injuries in; Lower Back Injuries and Low Back Pain; Musculoskeletal Tests, Spine; Slipped Disk; Young Athlete

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SCUBA Diving, Injuries in

Exploring the underwater world is a wonderful experience enjoyed by a wide variety of people. However, diving involves risks to health not encountered in other sporting activities and should not be attempted without certified instruction and assessment by a knowledgeable physician. This entry gives a brief overview of some common problems associated with diving and how to avoid them.

Diving can be done by swimming on the surface while breathing through a snorkel, holding your breath, or breathing compressed air from a tank or a hose (hookah). Problems can arise when the diver descends underwater because the pressure exerted by the water above the diver's body increases with depth. If this increased pressure unequally compresses the air and fluid spaces in the diver's body, an injury may result. In addition, breathing compressed gas at depths may cause another set of problems as gas is absorbed into the tissues, fluids, and spaces of the body. When the diver ascends to the surface, if the subsequent release and expansion of those gases occur in a rapid and uncontrolled manner, an injury known as decompression sickness may result.

Problems Caused by Water Pressure

Perhaps the most common problem in diving is the "ear squeeze," which results from the compression of the air behind the eardrum. Most of us experience this when diving to the bottom of a swimming pool. Special swallowing maneuvers can equalize the pressure in this middle part of the ear by opening the eustachian tube, which connects the throat with the middle ear. In a person with nasal congestion, the eustachian tube may be blocked, and equalization maneuvers may not work. Increasing the depth and pressure without equalization will eventually result in eardrum rupture and bleeding in the middle ear. While this may relieve the pressure difference and the pain, it can cause permanent damage or, worse, a sudden disequilibrium that could complicate a safe return to the surface. It is important not to dive when nasal congestion is present and middle ear equalization is not possible. Unless decongestants or allergy medications completely resolve nasal congestion and do not cause any side effects such as drowsiness, diving should be postponed. A similar, milder squeezing of the middle ear occurs when an airplane passenger descends to the higher air pressure at ground level.

The sinuses can similarly be "squeezed" and injured by increasing pressure as a diver descends, especially if nasal congestion blocks the sinus openings, preventing equalization. "Mask squeeze" occurs when the air in the mask is compressed and the mask presses on the face. It can cause headaches and bruising but is easily avoided with techniques learned in a diving course.

Problems Caused by Breathing Compressed Air

All gases, including the nitrogen and oxygen in ordinary air, can cause problems when they are breathed at increased pressures underwater. Compressed nitrogen can cause a mildly euphoric state with impaired judgment, which could be fatal for the diver or his buddy. This nitrogen narcosis is sometimes called the "rapture of the deep." Oxygen, which is lifesaving in many situations, can cause lung damage or even convulsions if breathed at high pressures. "Technical divers," who perform prolonged or very deep dives, often fill their tanks with special mixtures of oxygen, helium, nitrogen, or hydrogen to avoid these problems. But all gases have the potential to cause toxicity in certain situations.

Problems Caused by Ascent (Decompression Illnesses)

Self-contained underwater breathing apparatus (SCUBA) regulators, which were invented by Jacques Cousteau and Emile Gagnan, make SCUBA diving possible. As the diver descends to a higher-pressure environment, the regulator makes increasingly pressurized air available to fill the lungs. Surprisingly, it is the return to the lower pressure at the surface that is more dangerous than the descent. To understand this, let us review two laws of physics that you learned in high school and possibly forgot shortly thereafter.

Boyle's law states that at a constant temperature, the product of the pressure and volume of a gas is a constant. Thus, if the pressure increases, the volume decreases, and vice versa. The real-world application is that as a diver returns to the lower pressure at the surface, the volume of the gas in his or her lungs expands. For this reason, it is critically important that the return to the surface be slow, controlled, and with attention to exhaling this increased volume of gas. Otherwise, the alveoli, the tiny sacs in the lungs where blood and air meet, may burst, resulting in a pneumothorax. This is a leak that causes air to collect outside the lungs and compress it. In a similar fashion, air in the middle ear or sinuses may cause injury as the volume increases—a reverse squeeze.

Henry's law states that at a constant temperature, the amount of a gas dissolved in a liquid is directly proportional to the pressure of that gas above or around that liquid. As the pressure changes, the amount of gas dissolved in the liquid also changes. In diving, we are mostly concerned with the pressure of a gas in the alveoli and the amount of that gas dissolved in the blood capillaries surrounding each alveolus. Henry's law reminds us that as the pressure of nitrogen (the main gas in compressed air) increases in the lungs, the amount of nitrogen in the blood also increases. Conversely, when the diver ascends, and the pressure of nitrogen in the lungs decreases, the amount of nitrogen that can be kept dissolved in the blood and tissues also decreases. Some of this nitrogen, following Henry's law, must come out of solution, usually in the form of bubbles. While our bodies have other ways of quickly exchanging oxygen and carbon dioxide, the exchange of nitrogen is limited to simple diffusion.

Therefore, there are two mechanisms that change the gases in the body on ascent from a depth. Henry's law describes the increase in the amount of gas coming out of solution in body tissues such as fat, muscle, organs, and blood, and Boyle's law describes how the volume of that or any other gas increases. This may produce two main categories of decompression illnesses—decompression sickness and gas embolism.

The first, *decompression sickness,* results from the collection of gas where it does not usually exist—in and around joints, muscles, and nerves. It has been called "the bends" because of a doubled-over posture that may occur in the victims. A less serious condition occurs when gas collects in the skin.

The second, *gas embolism,* arises from bubbles in the blood causing the blockage of small arteries. Most people are familiar with embolic blockages of the blood vessels caused by blood clots in the heart or brain, which cause heart attacks or strokes. In a similar fashion, gas bubbles may cause embolic blockages in small arteries, with the same effects. While the heart and brain are the most common places for serious damage from gas emboli, other organs such as the kidneys and lungs can also be affected.

In addition to blocking the small arteries, the increasing size of the bubbles or gas collections may burst things. Even the small decrease in pressure that occurs when ascending in a pressurized aircraft might add to decompression from diving, and, therefore, air travel should not occur for several hours after diving.

Decompression sickness and gas embolism can usually be prevented through careful attention to diving techniques, especially ascending in an orderly, planned, and controlled fashion. If they do occur, initial treatment is breathing pure oxygen, which decreases the amount of nitrogen in the lungs, favoring the diffusion of nitrogen out of the tissues because of the resulting gradient.

A decompression illness that is not improving or results in serious symptoms should be treated in a hyperbaric (high-pressure) chamber, where the patient can be returned to high pressures in the hope of returning the gas to solution and then decompressing slowly, thereby allowing the gas to come out of solution gradually without causing damage. (One such hyperbaric center is The Duke Center for Hyperbaric Medicine and Environmental Physiology: 919–684–6726, Hospital 24 Hour 919–684–8111.)

Specific Injuries and Medical Concerns

Asthma may cause narrowing of the small airways, which could make equalization of pressures difficult and increase the chance of pneumothorax and gas emboli if alveoli burst in an area that cannot be equalized. Traditionally, persons with asthma were prohibited from diving. However, current recommendations are that well-controlled asthma is usually compatible with diving if the candidate is symptom-free with medication. What is critical is that the asthma be well controlled. All persons with asthma, but especially divers, must see a physician and take prescribed medications regularly to ensure optimal control. Conversely, on a related topic, anyone who has had a spontaneous pneumothorax should not dive. Chest X-rays are often done as part of a diving examination to look for this, but previous pneumothoraces are usually not detectable, and so a medical history is important in these cases.

Seizures, dizziness, migraine headaches with vision or balance changes, and panic attacks are other conditions that may not be too concerning in ordinary activities; however, if they occur under water, a safe return to the surface may be compromised, and their occurrence may be fatal. Similarly, symptoms of heart disease, which might be treated easily on the surface, may lead to drowning if they occur under water. Persons with these conditions are usually advised not to dive. In addition, a minimum level of physical fitness is required to dive safely because the diver may be confronted with unexpected challenges from weather, currents, temperature, and other physical conditions related to the diving environment. Also important is the possession and practice of good judgment to avoid situations that increase the risk of accidents.

Additional information can be requested from the Divers Alert Network, a nonprofit organization that maintains a comprehensive website and an emergency hotline for diving accidents (www.diversalertnetwork.org; 919–684–4DAN [4326]).

Ronald P. Olson and Jake Freiberger

See also Ear Infection, Outer (Otitis Externa); Surfing, Injuries in

Further Readings

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Seasonal Rhythms and Exercise

Changes in seasons across the calendar year lead to variations in the weather and environmental conditions in most locations across the globe. Such variations exhibit a period of about 1 year ± 2 months and, thus, can be defined as "seasonal" rhythms. Seasonal rhythms are influential in determining patterns of behavior in a wide range of living organisms. These rhythms also have the potential to affect human behavior as we: (a) possess an internal body clock that is responsible for subtle rhythmic changes in a range of physiological functions across various time periods, and (b) are susceptible to the demands of external factors. The spatial distribution of humans across a wide range of climatic zones means that variability in environmental conditions across the calendar year is a common experience for most people. This makes understanding the potential impact of these seasonal changes on important social behaviors such as exercise, in both the recreational and the elite athlete, useful to the sport and exercise scientist. This knowledge may help inform the development of effective interventions to enhance health-related fitness, as well as highlight the best strategies for competitive athletes in optimizing performance.

The Basis for Seasonal Rhythms

Seasonal rhythms are linked to fluctuations in the prevailing climatic conditions observed at any given time of the year. These climatic conditions are, in their simplest terms, a direct consequence of the daily axis of rotation of the earth being inclined at 23.5° from the vertical and the elliptical orbit of the earth around the sun. This tilted orientation produces a seasonal variation in the duration of daylight from the equator to the poles. The angle at which the rays of the sun strike the surface of the earth also varies according to the season. This leads in turn to marked differences in the ambient temperature and other climatic and weather conditions that partly depend on the latitude and the prevailing topography. Such environmental changes, along with alterations in the amount of daylight, have the potential to be very influential on human social behavior. This is especially pertinent to activities, such as exercise, in which such environmental factors will affect important characteristics of the exercise stress (e.g., type, frequency, duration, and intensity). Changes in these variables will subsequently have consequences for both the acute physiological responses to exercise and the adaptations that follow chronic exposure to activity in both a health setting and a performance setting.

The potential theoretical importance of seasonal rhythms is not currently reflected in the amount of available research in the field. Methodological issues have undoubtedly had an effect as appropriate experimental designs and methodologies are very difficult to use in this field. More important though is our increasing ability to control both our climatic conditions and our exposure to light in our immediate surroundings. As a result, our habitual activities and behaviors are in theory no longer tightly bound to seasonal fluctuations in day length and climate and are more likely to depend on cultural, religious, and economic influences. These influences will clearly reduce the amount of the seasonal variability to be observed in human populations in Western industrialized societies and, thereby, potentially limit the ability of such rhythms to influence behavior. Nevertheless, seasonal variation can still affect many aspects of the work of the sport and exercise scientist, especially when the external environment strongly facilitates or acts as a barrier to exercise participation.

Seasonal Variation in the Physiological Responses to Exercise

The seasonal variation in ambient temperature and environmental conditions provides one basis for the existence of seasonal rhythms. Aspects such as metabolic rate and the physiological response to a given exercise stress are highly susceptible to such changes. This may either result in alterations in the social behavior of individuals or act to change the underlying physiology, a process known as acclimation. Characteristics of the human thermoregulatory system exhibit seasonal variation primarily as a consequence of acclimation. Sweating, a vital component of the body's heat loss response during exercise, is altered both with respect to its initiation and amount during summer because of the repeated exposure to elevated temperatures. Other thermoregulatory changes include variations in the core temperature response to an exercise stress and altered individual subjective thermal sensations to a given heat challenge. The time of the year can also affect other aspects of the exercise response, including causing changes in the hematocrit and alterations in the respiratory exchange ratio, with relatively more fatty acids being used as a fuel in the winter. Such changes may be partly mediated by the changes in body temperature associated with exercise because the core temperature is an important determinant of the metabolic response to exercise, elevating carbohydrate usage when levels are high.

Annual cycles in day length are also relevant to the existence of circannual rhythms as they have the potential to alter both the intrinsic elements of the body clock and exogenous behavioral factors. The relationship between seasonal changes in both day length (photoperiod) and night length (scotoperiod) and the behavioral, metabolic, and biochemical responses to exercise in humans remains uncertain. Seasonal changes of the natural photo- and scotoperiods at high latitudes have an effect on melatonin secretion in humans as discussed previously, though there is no consensus on whether humans generally display a seasonal rhythmicity in melatonin secretion. This limits the direct evidence that is available to support the theory that changes in the extent of melatonin control the effect of photoperiod, as occurs in animal models. Evidence that other circadian rhythms also display seasonal variation is also relatively weak in healthy humans. This may suggest that humans in industrialized countries live in environments in which the photoperiod may have lost its status of primary *zeitgeber* (a cue that synchronizes a person's "internal clock" to the earth's light/dark cycle).

Seasonal Variation in Physical Activity Patterns

Substantial evidence exists for significant seasonal variation in the physical activity of free-living adults in most industrialized countries. These changes display a sinusoidal pattern, with peak values occurring in summer for the majority of measures of physical activity. The most common habitual physical activities associated with leisure, such as walking for pleasure, gardening, lawn mowing, bicycling, hiking, and running, all display significant seasonal variation in industrialized populations. A variation in occupational activities seems to be able to explain less of the variability in activity patterns unless the local population is nonindustrialized and is, therefore, subject to specific periods of high levels of activity (e.g., during harvesting of crops). These reductions are also observed in humans who live at high latitudes during periods when one would assume that physical activity would be desirable to help protect against the climatic conditions. Changes in daylight hours seem to be important in these variations, though the more favorable environmental conditions in summer to carry out an active lifestyle will no doubt also play a role.

Seasonal Variation in Physical Fitness and Health

The maintenance of physical activity over the whole year is important for the health of individuals. Such changes in activity are also likely to have consequences for alterations in physical fitness. The best aerobic performances are frequently recorded in subjects at summertime—that is, unless individuals maintain high levels of physical activity in winter in specific recreational activities (e.g., winter sports such as skiing). These circumstances may limit the reductions observed in fitness and lead to more stable performance levels across relevant time periods. The impact of seasonality on health-related issues is, however, much more complicated as these relationships can be extremely variable and complex. It has been suggested that the month of birth may be related to the susceptibility to certain illnesses, though these associations should in no way be interpreted as being indicative of a direct relationship between different times of the year and disease risk. Changes in activity across the annual cycle may also compound problems with glycemic control in Type 2 diabetics. Epidemiological data do, however, highlight the idea that the incidence and mortality of cardiovascular disease, such as coronary heart disease, is increased in winter compared with the spring. This trend may be related to the seasonal variations in a number of risk factors (e.g., body weight, oxidant/antioxidant processes, calorie intake) as a result of changes in temperature, lifestyle, and human physiology (e.g., blood pressure). These relationships would indicate that such variations in cardiovascular-related morbidity may be reduced by the careful modification of external environmental factors, such as better housing, improved heating, and changes to seasonally driven lifestyles.

Viral infections and influenzas are also more likely in the colder months, with the most commonly cited explanation being the increased "crowding" indoors of susceptible persons in the winter. Exercise-induced bronchospasm also shows seasonal variation, with a twofold increase in incidence in dry seasons compared with other times of the year. This would suggest that such conditions may be complicated by environmental factors such as dry air, the ambient temperature, and the presence of environmental allergens, such as pollen, in individuals. Mental health may also be more susceptible to challenges at certain times of the year. The long hours of darkness in winter, especially in the northern latitudes, can lead to a depression known as *seasonal affective disorder*. The seasonal effect on the diurnal rhythm in melatonin may partly explain these occurrences and open the possibility of the use of a combination of bright light and exercise as a therapeutic tool.

Seasonal Variation in Competitive Sports Performance

The types of sports in which athletes participate, as well as the training behavior of elite athletes, are clearly influenced by the seasonal changes in the weather. Skiing, ice skating, hurling, and ski jumping are naturally all "winter sports," while other sports, such as cricket and tennis, are primarily played in the warmer summer temperatures. The distinctness of the temporal location of such activities within the calendar year has recently become blurred, with the development of indoor facilities that allow a variety of climatic conditions to be simulated. The accessibility of long-distance travel across hemispheres to reverse seasons has also enabled competitions to be scheduled at nontraditional times. As climatic conditions vary as a function of the time of year and geographical location, it is likely that athletic performances could be associated with additional physiological demands in some circumstances. For example, changes in environmental conditions, especially the ambient temperature, will alter the metabolic and physiological responses to a range of exercise stresses. The increased presence of seasonal allergens such as pollen may also compound any physiological changes. Travel across time zones will also not be without its own consequences if events are scheduled close to arrival times as the athlete groups involved may face additional difficulties in preparing for competition.

An understanding of the seasonal variation in sports performance is also complicated by exogenous factors that mask any inherent endogenous circannual rhythms. Elite athletes "periodize" or "cycle" their training throughout the year. Periodization involves the adoption of cyclic variations in the intensity and type of training stimuli and the amount of rest. The calendar year is traditionally divided into three distinct phases: the preparatory period, the competitive period, and the recovery phase, each of which has its own specific objectives and associated training load. It is therefore of little surprise that variations in performance in a range of physiological parameters (e.g., maximal oxygen consumption, anaerobic power, isometric and isokinetic strength, body composition) are associated with the different training phases that are adopted. This evidence would suggest that seasonal changes in performance are a consequence of external factors rather than any inherent internal seasonal rhythm.

More conclusive evidence for circannual rhythms in competitive sports performance may come from the observation of subtle differences within specific phases of the periodized year. Using this approach, a significant component of the exogenous changes in activity associated with the periodized year should be removed as the training stimulus should be much less variable. Team sports such as soccer show such subtle variations in the work rate completed by players during games at different stages of the competitive season. Such variations are not associated with alterations in the physical capabilities of players or their physiological characteristics as these do not tend to vary greatly within the competitive season. Large inter-individual differences in these data, as well as a failure to control other known determining factors of a player's work rate (e.g., opposition), do, however, preclude firm conclusions regarding the origin of these variations to be made on the basis of the data currently available.

Future elite performers may also be dictated partly by an observed seasonal birth bias. Age categories in youth sports are often managed by having a birth cutoff point to determine eligibility. Comprehensive evidence from a number of athletic groups (e.g., soccer, hockey, baseball) indicates that participants in underage teams tend to be born at the start of the competitive year. This provides these individuals with a chronological advantage over those born later in the year, which tends to be replicated in a maturational superiority. This early selection bias can carry through to those selected for elite adult competitions in later years. This phenomenon cannot be attributed to any endogenous circannual rhythm as the bias can be altered if the initial date for eligibility is changed. As such, coaches and selectors are advised to acknowledge the influence of such factors and compensate for them accordingly.

Another area directly relevant to competitive sports performance that displays a high degree of seasonal variation is the incidence of injury. There is clear seasonality in the frequency of injuries incurred by athletes participating in a wide range of sports, though this variation differs between sports. The highest injury rates seem to occur during the competitive season rather than the preparation periods. The multifactorial nature of the causes of sports injuries makes it very difficult to clearly attribute these differences in injury to any one specific factor. It is clear that a variety of exogenous factors, such as environmental conditions (both high and low temperatures can increase the risk of injury) and changes in the amount and intensity of activity, can predispose an individual to injury. Endogenous factors may also play a role. For example, vitamin D levels in the body can be increased in response to environmental light. This fat-soluble vitamin promotes growth and mineralization of bones and increases the absorption of dietary calcium. This may mean that bone mineral density varies seasonally, with the lowest values observed in the winter months. This, when combined with the low levels of activity at this time of year, may lead to a weaker skeleton and increase injury disposition. Such changes may, however, be minimal in an athletic population that maintains high levels of activity across the calendar year.

Barry Drust

See also Circadian Rhythms and Exercise; Exercise and Disease Prevention; Performance Enhancement, Doping, Therapeutic Use Exemptions; Periodization; Shift Work and Exercise

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Seizure Disorder in Sports

A seizure is a common, serious neurological event affecting approximately 10% of individuals during their lifetimes. Each year, an estimated 300,000 individuals in the United States, including 120,000 children and adolescents, will experience their first seizure. Team doctors and coaches should be familiar with caring for an athlete who has a seizure during an event. While athletic participation is generally encouraged for individuals who have had a single seizure or diagnosis of epilepsy, many factors are considered. This entry discusses recent guides for participation, safety and first-aid measures, and special considerations for athletes with a seizure disorder.

Definitions and Risk of Recurrence

The brain normally functions through a network of neurons that send and receive bioelectrical signals maintaining our homeostasis at rest and performing purposeful activities. In simple terms, a *seizure* is a neurological event during which normal brain messaging is interrupted by chaotic neuronal hyperactivity, resulting in loss of targeted function. *Epilepsy* is a condition in which an individual is susceptible to recurrent seizures.

Seizures originating in a discrete, localized region involving one side of the brain are called *focal* or *partial seizures.* Focal seizures are categorized into simple seizures, in which specific functions (e.g., unilateral muscle twitching) are affected, and complex seizures, in which the mental alertness and state of consciousness are affected. Typical clinical features include unresponsiveness, staring, or confusion, as well as gaze deviation, lip smacking, drooling, or semipurposeful hand movements. This abnormal bioelectrical activity can continue to spread to the opposite cerebral hemisphere, resulting in a secondarily generalized tonic-clonic seizure, historically described as a *grand mal* seizure or *convulsion.* Focal seizures may be caused by a variety of recognized pathology, including trauma, stroke, tumor, developmental structural abnormality, or infection irritating certain regions of the brain. Often, no clear cause or etiology can be determined.

A generalized seizure involves both cerebral hemispheres. The various subtypes of generalized seizures include absence, myoclonic, atonic (drop events), and generalized tonic-clonic. Absence seizures are brief, abrupt staring episodes or lapses in attention, most commonly seen in children. Myoclonic seizures are shocklike muscle twitches, most commonly presenting in adolescents. Primary generalized seizures often recur, typically have genetic etiologies, and commonly result in a diagnosis of epilepsy. Some conditions such as juvenile absence epilepsy and juvenile myoclonic epilepsy require lifelong therapy.

For the witness to a seizure, it is helpful to record the duration, recurrence, and clinical features of the seizure, such as the side of the body involved and the injuries sustained. A medical evaluation is required for anyone experiencing a first seizure. Through this evaluation, an electroencephalogram (EEG), neuroimaging, and consultation with a neurologist will determine the likelihood of recurrence and any necessary preventive therapy. A safety plan will also be devised in the case of a future seizure.

The overall risk of additional seizure in an individual having a single focal seizure is approximately 30% to 50%, while primary generalized seizures are very likely to recur without treatment. Some clinical factors may provoke a seizure, but it is important to make these determinations and any activity restrictions on an individual basis. Typical exacerbating factors include fever/infection, sleep deprivation, alcohol, some specific medications, and noncompliance with prescribed preventative anticonvulsant therapy. Many patients report stress and "overactivity" as factors, though these are hard to systematically evaluate and define. Rare cases of reflex epilepsy have been associated with aerobic exercise, reading, or other specific stimuli. Hyperventilation may provoke some generalized seizures though athletic participation and exertion typically do not. While traumatic brain injury can provoke a seizure, participation in contact sports, such as football or hockey, has not been shown to trigger seizures. Although precautions and an individualized plan are essential, aerobic exercise and athletic participation are recommended for individuals with a single seizure and for those with epilepsy.

Participation Guides

While athletic participation is encouraged and has clear health benefits, risks should be addressed in a thoughtful, practical manner in each individual setting. This risk-benefit analysis will consider the seizure type, likelihood of recurrence, present control, potential injury should a seizure occur, and reasonable safety precautions deployable. In 1997, the International League Against Epilepsy trimmed the list of restricted activities to self-contained underwater breathing apparatus (SCUBA) diving and sky diving. Obviously, some activities involve higher degrees of scrutiny and absolute seizure control, such as motor sports and precision shooting/archery and activities involving heights, such as rock climbing. Gymnastics, horseback riding, sailing, and swimming/diving are other sports requiring discretion, close supervision, and control of seizures prior to participation, due to risks of personal injury. Cycling, skating, and skiing also require seizure control and routine personal protection such as helmets. Contact sports such as football, hockey, and soccer do not have restrictions beyond close supervision and routine safety procedures. Aerobic activities and weight training should be undertaken with typical safety precautions. The speed, intensity, and setting of the activity will dictate the necessity of seizure control prior to participation as many individuals with active, uncontrolled epilepsy benefit from jogging, golf, and court sports such as tennis and basketball.

Safety and First Aid

In the event that an individual experiences a seizure, simple first-aid measures can be promptly implemented. Although a seizure can be initially alarming, a calm, reassuring manner is helpful. First, prevent any additional injury, protecting the patient from falls, collisions, or drowning. Time the duration of the event, and note clinical features if possible. Do not restrain the individual. Loosen tight clothing if possible. If safe, turn the individual on his or her side as some individuals have excess secretions and may vomit, although rarely. Also, do not place an object in the individual's mouth that could create the potential for choking or dental damage. The person having a seizure will not swallow his or her tongue, as is commonly misconceived. Stay with the individual and seek emergency medical care (911) if the seizure lasts longer than 3 minutes. Some individuals with epilepsy may have rescue medications available that are typically used after a 3-minute seizure duration. If the seizure is recurrent or provoked by head trauma or the individual fails to demonstrate recovery over a 10-minute duration following the event, the individual should also be evaluated on an emergent basis. If it is the person's first seizure, a prompt evaluation is important. While emergency care is important for many, if the individual has recognized epilepsy and a self-resolving seizure lasting less than 3 minutes, emergency care may not be necessary. Many individuals feel tired, confused, and complain of headaches following a seizure; however, they should be able to be aroused and follow simple commands. It is important to stay with the individual until he or she has recovered. An individual who experiences a seizure should not return to immediate athletic participation. The Epilepsy Foundation of America has produced informative educational materials (www.epilepsyfoundation.org).

Prevention and Therapy Considerations

Therapeutic plans for individuals with epilepsy or for those who have experienced a single seizure often include a rescue medication in the event of a prolonged seizure lasting more than 3 minutes. These medications are typically a benzodiazepine such as diazepam or lorazepam, given by a rectal or buccal preparation. Nasal midazolam is beginning to be accepted as an alternative.

Preventative anticonvulsant medications, if necessary, should maximize the efficacy and tolerability. Clear cognitive function and alertness are critical to athletes. Lamotrigine and levetiracetam are medication options with infrequent sedation. Topiramate and zonisamide are effective medications for many types of epilepsy; however, for the athlete, special attention must be paid to hydration status and temperature control as these medications lead to a high incidence of kidney stones and reduced sweating, increasing the risk of hyperthermia and heat stroke.

Jason Doescher

See also Emergency Medicine and Sports; Fieldside Assessment and Triage; Physically and Mentally Challenged Athletes

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Senior Athletes

Although some have suggested that the increased level of injuries diagnosed within the aging population is due to simply "outliving our warranties," a look into the subculture of senior—or masters—athletes reveals a number of individuals who are outperforming society's age-defined expectations. Athletes in the media spotlight, such as football player Brett Favre, cyclist Lance Armstrong, and swimmer Dara Torres, are redefining how we think about aging. However, these feats of enduring performance are not limited to elite-level athletes: Recreational athletes, including those who are abandoning the couch in pursuit of a more active lifestyle, have demonstrated some remarkable accomplishments of their own. Despite the fact that waiting rooms at doctors' offices across the country are filled with these "weekend warriors," sports medicine has largely ignored this group, preferring to focus on the child, collegiate, or professional athlete. The purpose of this entry is to illuminate the factors affecting performance and injury prevention in the aging athlete and to summarize the benefits of active aging, thereby dispelling the common notion that age is the sole factor contributing to an individual's activity level.

To maintain an active lifestyle as we age, it is important to understand the biology behind the aging process. At the cellular level, rapid cell division provides the human body with a remarkable regeneration capacity. It enables us to recover from injury rapidly throughout the childhood and early adult years. As we continue to age, our bodies become less efficient at these regeneration activities, resulting in stiffer tissues and a decline in overall performance. These changes occur not only at the macrolevel of muscles and joints but also at the microlevel of deoxyribonucleic acid (DNA). The way our genes are expressed also changes with age and activity level. The consensus among the general population is that this lapse in athletic prowess is an inevitable and irreversible part of the aging process. This consensus, however, is less grounded in science than in anecdote. Many studies are revealing the true capacity of our musculoskeletal system with aging and show that aging is not necessarily an irreversible decline from vitality to frailty.

We know from recent research efforts that "old" cells can be reprogrammed at the cellular level to behave like "young" cells by simply using exercise as medicine. In general, much more investigation into this decline and how much can be attributed to physical inactivity is needed. The high level of physical activity maintained by masters athletes throughout their lifespans make them model subjects for investigating healthy aging. By studying this population, we are able to eliminate the variable of physical inactivity or other health conditions when investigating the aging process.

The Longevity of the Masters Athlete

Masters athletes everywhere continue to debunk the common myth that turning 40 means slowing down. In a survey conducted by the Arthritis Foundation, 64% of masters athletes reported feeling an average of 11 years younger than their actual age, while 40% reported living a more healthy and physically fit lifestyle than in their 20s. Moreover, 33% of them boasted that they could beat their children in at least one sport. It is important to note that these people are not the exception but the standard. All individuals have the chance to maintain this high quality of life and functional capacity throughout their lifespans if they choose to avoid a sedentary lifestyle. Studies of performance decline in masters athletes indicate that the slowing phenomenon of the aging process does not have a significant impact until the seventh decade of life.

In a study of track athletes between the ages of 50 and 85 who participated in the 2001 National Summer Senior Games, running times across all distances declined with age. While this trend was expected, the surprising finding was the small degree of performance decline that occurred with age. Until the age of 75, the observed decline was slow and linear, with decreases of less than 2% per year. This decline was not found to be statistically significant. At age 75, however, the rate of decline jumped to approximately 8%. This trend of performance decline with age is shown in Senior Olympians competing at all distances, from the 100-meter (m) dash to the 10,000-m run. These results suggest that if disuse and disease are eliminated, individuals should be able to maintain high levels of functional independence until the age of 75. Therefore, the loss of independence before the age of 75 must be attributed to lifestyle habits, disease, or genetic predisposition.

Similar rates of maintained performance are also observed when investigating the scores of masters athletes on tests of aerobic capacity, such as the $\dot{V}O_2max$ and the lactate threshold test. An analysis of the $\dot{V}O_2max$ (peak oxygen uptake) scores of masters athletes over the age of 35 proposes that a 0.5% decline per year may be an intrinsic biomarker of the aging process. Women have displayed a slightly faster rate of decline than men in this area. These rates are much less than would be expected considering that a low $\dot{V}O_2max$ is believed to be one of the fundamental reasons behind decreases in functional capacity in the aging population. Research investigating declines in endurance performance with aging attributed poor performance to a reduced $\dot{V}O_2max$ and lactate threshold. In a study comparing healthy young adults, older sedentary individuals, and older endurance athletes, approximately 50% of the age-related differences witnessed in the $\dot{V}O_2max$ score were found to be the result of a smaller stroke volume. The remaining differences were attributed to a lower maximal heart rate and reduced oxygen extraction. However, as shown within the masters athlete group, these trends can be greatly diminished through high levels of habitual exercise. This suggests that any exaggerated rates of decline are the results of lower energy levels, decreased training intensity, and less time spent training. Only modest portions of these declines in performance are age related.

These moderate rates of performance decline also depend on factors such as gender and type of physical activity. Investigation of track-and-field records to examine the rate of performance decline show that strength deteriorates before stamina does. This is best seen in sprinters, as their declines in running speed are paralleled with a decrease in stride length. This is believed to be the result of a decrease in muscle strength, which requires athletes to take a greater number of strides to cover the same distance. However, when examining the times of Senior Olympian record holders, it was found that the rates of decline were most prominent among the endurance athletes. In swimmers, the sex differences were largest in the sprint events and smallest in the distance events. The data examining the rates of performance decline among types of swimming events also yield conflicting results, as some studies report a larger decline in sprint races while others find a larger decline in endurance races. Parallel to the runner's decrease in stride length, swimmers demonstrate a decreased stroke length, which results in an increase in stroke frequency. It is believed that the mechanisms of decline are different for each sport, depending on the demands of the activity; yet altogether, they remain gradual.

Injuries in Masters Athletes

The magnitude of evidence in favor of active aging raises an important question: If masters athletes are so healthy, why are they getting hurt? According to the U.S. Consumer Products Safety Commission, a 33% increase in injuries was witnessed within the masters athlete population from 1991 to 1998. Injuries are the number one reason for the stoppage of physical activity in this group and occur highest in sports such as cycling, basketball, baseball, and running. Investigation of the mechanism of these injuries reveals that 69% of masters athletes attempt to work through their pain to remain active. This is most likely why 60% of the injuries reported are the result of overuse and only 23% are the result of falls. Research has suggested a number of reasons for the increased incidence of injury witnessed within this group, the most notable of which is inappropriate training methods. Unpublished data from a study conducted by Wright and colleagues reveal that in a sample of masters athletes surveyed, 50% of the athletes devoted 5% or less of their total training time to stretching exercises. Of that group, 31.5% devoted only 0% to 2% of their time to stretching activities. This is without question an insubstantial amount of time. To avoid injury, masters athletes must train smarter than they did in their younger years. This includes proper nutrition, not overextending oneself when training, and adequate amounts of daily stretching, especially before intense bouts of exercise.

Muscle

Acute muscle strains account for a predominant portion of the injuries witnessed within the aging population. This is attributed to loss of flexibility as well as weak or fatigued muscles. The predisposition of masters athletes to these injuries is thought to be the result of their frequent participation in endurance sports. Investigation of the mechanism of these injuries reveals that the athletes often report changes in their training activities when recounting the onset of the injury. This supports the belief that older athletes do not transition from sport to sport as quickly as they did in their younger years and require a more extensive warm-up before commencing rigorous physical activity. Furthermore, all individuals have a responsibility to exercise, no matter at what age, to maintain stronger, resilient muscles that are more resistant to injury.

Tendon

Tendinosis in masters athletes commonly occurs as the result of overtraining. This subjects the tendon to repetitive microtrauma, which in turn causes it to stiffen. Other factors that can contribute to this age-related stiffening of connective tissues are decreases in water content, increases in elastin fibril thickness, and hormonal abnormalities, such as diabetes mellitus or an excess of corticosteroids. Three of the most prevalent types of tendinosis in masters athletes are rotator cuff tendinopathy, Achilles tendinitis, and tennis elbow. All this suggests that the gradual stiffening of tendons must be paralleled by changes in the masters athlete's training regimen if he or she is to avoid these injuries. Daily stretching exercises are paramount in avoiding tendon stiffening and the subsequent tendinosis.

Knee

In recent years, the consensus that exercise provides protective benefits to joints by reducing the incidence of degenerative diseases, such as osteoarthritis, has been a controversial issue. Traditionally, the prescribed therapy for knee pain has been modification of training activities, a technique not well received by many masters athletes. This makes the management of knee osteoarthritis one of the most challenging issues in sports medicine today since those affected by this disorder typically wish to maintain a high level of physical activity. Investigations of this disorder reveal that athletes symptomatic for knee osteoarthritis all demonstrated quadriceps weakness, reduced proprioception, and increased postural sway. Altered proprioception due to muscle fatigue may weaken the neuromuscular response and decrease the efficiency of protective muscular reflexes. This contradicts the paradigm that the aging athlete should not participate in activities that subject the knees to high levels of impact, such as running, as knee injuries can be avoided by maintaining quadriceps, core, and hip strength, as well as refraining from high-intensity workouts when fatigued.

Shoulder

Shoulder injuries, such as subacromial impingement and rotator cuff tears, are commonly associated with repetitive shoulder motion. Initially, the goal of shoulder surgery was to alleviate pain symptoms. Currently, the goal is to achieve a return to physical activities, which is becoming increasingly more common. Patients over 65 years demonstrate great success in recovering from subacromial decompression and rotator cuff repair, with a 94% satisfaction rate. The majority of these patients report a reduction in pain symptoms, independent living, and return to sports. Research investigating return to sports suggested that 80% of patients return to sports at their previous level of competition following surgery to their dominant shoulder. However, this becomes increasingly more difficult as patients pursue higher-intensity, higher-impact sports. Despite the success rates of these surgical procedures, these injuries are best treated through preventive efforts. Many athletes focus on building the "cosmetic" muscles, such as the biceps, triceps, and deltoids, while ignoring the exercises that work the smaller muscles, which are paramount for joint stability and avoiding injury.

Hip

Studies of women with lower extremity osteoarthritis revealed that fatigue was strongly associated with physical activity, while pain was more weakly associated with physical activity and was in the direction opposite to what was expected. This stresses the importance of fatigue management in helping masters athletes with osteoarthritis maintain high levels of physical activity. Hip arthroscopy is a method commonly used to treat labral tears and the early stages of osteoarthritis. It has yielded reproducible results in the diagnosis and treatment of intraarticular hip disorders in elite athletes. Hip arthroscopy could be a promising treatment for the aging population as many elite masters athletes refuse to modify their activities and do not have the degenerative changes to warrant joint replacement. Regardless of activity levels, the senior population will exhibit a redistribution of joint torques from plantarflexion to hip joint extension over time. However, the active elderly display a more pronounced increase of hip extension torque, which enables them to perpetuate the support torque at the level of young subjects. This age-related redistribution of joint torques is of pivotal importance since the active elderly use it as a means of compensating for diminishing muscle function. By maintaining flexibility, core, and gluteal strength, masters athletes may avoid hip injuries and continue to enjoy high levels of functional capacity.

Changes That Occur as We Age

Natural Aging: The Cardiovascular System

In the aging process, upkeep of cardiovascular function is imperative: Forty percent of deaths in people between the ages of 65 and 74 are the result of heart disease; for individuals over the age of 80, this proportion jumps to 60%. This is because many age-related physiological changes are witnessed in the cardiovascular system. For example, a 70-year-old heart has 30% fewer cells than the heart of a 20-year-old. The cardiac output of a 20-year-old is 3.5 to 4 times his or her resting capacity, while an 80-year-old can output only twice his or her resting capacity. During exertion, the maximum heart rate for a 20-year-old is between 180 and 200 beats per minute (bpm), while it is only 145 bpm for an 80-year-old. To some extent, these changes are part of the natural maturation of the heart. As part of the aging process, the maximum heart rate, the stoke volume, and the contractility of the heart will decrease. In the arteries, a decreased elasticity occurs, which results in a narrower space for blood to flow from the heart. This produces a rise in blood pressure and forces the heart to pump harder, which eventually leads to a thicker left ventricle. All these changes disrupt the heart's delivery of oxygen to the tissues, which affects performance, metabolism, and energy levels. Although these physiological changes may appear alarming, chronic high-level exercise and a healthy diet have long been associated with healthy cardiovascular function and a slowing of these changes.

Masters Athletes: The Cardiovascular System

Through endurance conditioning, one is capable of modifying maximum oxygen consumption, diastolic filling and relaxation, and arterial stiffness. In a prospective study of masters athletes across 20 years, less than 14% evidenced risk factors for coronary heart disease at the 20-year evaluation point. In addition, a study of the effects of vigorous endurance training reflected a low prevalence of hypertension in masters athletes when compared with controls, with the masters athlete group being 27.8% less likely to have used medication for hypertension at any time. While a lower body mass and decreased body weight may explicate this effect, researchers believe that other mechanisms exist whereby exercise may induce a decreased rate of hypertension.

Natural Aging: The Muscular System

Sarcopenia, or the loss of lean muscle mass, is one of the major contributors to the loss of independence in the aging population. This is because large decrements in muscle mass will lead to an increased risk of injury. As with the heart, skeletal muscles will lose cells as they age, as well as exhibiting increased stiffness and a reduced size of the muscle fibers, beginning around the age of 50. These changes result in a decrease in muscle mass, which in turn produces an equal or greater decline in muscle strength and power. In the sedentary population, this loss of lean muscle mass is approximately 15% per decade between the ages of 50 and 70. After 70, this loss reaches approximately 30% per decade. The clinical impression is that these changes are the result of compositional changes of the muscle as research has shown an increased fat infiltration in the muscle of the aging sedentary population. However, recent studies of masters athletes have discovered that this is not the case.

Masters Athletes: The Muscular System

A study of masters weight lifters revealed a muscle deterioration rate of 1.0% to 1.5% per year. Additional studies determined that an 85-year-old weight lifter is as powerful as an inactive 65-year-old. This indicates that competitive performance throughout the later life stages is still feasible and that maintaining an increased level of physical activity in late life is imperative for healthy aging. Furthermore, analysis of anaerobic muscle performance indicated that age-related rates of decline in women exceed those of men but only in events requiring explosive power. It is in these events that we witness the largest rates of decline for both sexes. To contest the paradigm that muscle undergoes many age-related composition changes, Wright and colleagues are currently conducting a study that investigates the role of chronic high-level exercise in preventing the loss of lean muscle mass and strength. Preliminary findings support the observation that fat infiltration did not increase with age and that total muscle area and quadriceps strength did not decline with age. This offers further support that by maintaining muscle mass and strength, masters athletes are able to stave off falls, functional decline, osteoporosis, or other factors that lead to the loss of functional independence.

Natural Aging: The Skeletal System

The loss of bone mineral density (BMD) associated with aging is another major contributor to the loss of independence in the senior population. Decreases in BMD can lead to osteoporosis, subjecting the individual to an increased risk of fracture. Risk factors for osteoporosis include decreased calcium intake, low levels of active exercise, smoking, and low levels of testosterone in men. The loss of bone mass is a major problem for both men and women over the age of 40. Women lose bone mass twice as fast as men, at a rate of 1.5% to 2% per year. This rate reaches 3% per year postmenopause.

Masters Athletes: The Skeletal System

When comparing whole-body BMD values of masters athletes and sedentary adults, the athlete group exhibited significantly larger values of BMD. In a study of masters athletes participating in the 2005 National Senior Games, it was found that the majority of the women had more normal bone density than weak bone density, even those who were more than 80 years old. The incidence of osteoporosis among this group of woman masters athletes was less than in the general population at any age. In other studies, a 0.8% increase in hip BMD was associated with each hour-per-week difference of high-level exercise in women. These increases were most prominent among premenopausal women. A study of femoral neck, spine, and whole-body BMD in men over 65 years of age determined that bioavailable testosterone, physical activity level, and body mass index (BMI) all contributed to the variance of BMD values at the femoral neck. Independent analysis of these three variables revealed that bioavailable testosterone accounted for 20.7% of this variance, physical activity for 9.0%, and BMI for 6.5%. Bouts of high-intensity resistance training resulted in sharp increases in testosterone levels in middle-aged and older men, which may further alleviate decreases in BMD. All this demonstrates that BMD may be maintained in the aging population through high levels of chronic exercise.

Natural Aging: Cartilage and Tendon

Both cartilage and tendon can deteriorate through atrophy or overuse. Maintaining these tissues is of primary concern for the aging population. Tendinitis is a painful inflammation of the tendon that is quite common in athletes over 40. This condition develops as the tendon experiences repetitive microtears through excessive movements or inadequate stretching prior to physical activity. The lack of stretching causes the fibers of the tendon to gradually become shorter. Tendinitis is most commonly seen in the elbow, wrist, biceps, shoulder, leg, knee, and Achilles. Ultimately, it occurs in the areas of the body that the individual uses most. Healthy cartilage can deteriorate by softening or fissuring. High-impact activities have been shown to exacerbate this wear of deteriorated cartilage. Fortunately, this is not always the case.

Masters Athletes: Cartilage and Tendon

These conditions can be easily avoided with smart training methods, such as a proper warm-up and stretching prior to strenuous physical activity. The best way to protect cartilage and tendon is to adequately address issues such as pain and fatigue as they arise. Ignoring symptoms such as pain or weakness will only subject cartilage and tendon to further abuse. Rest and moderation of training activities are imperative to protect the health of the body's cartilage. If masters athletes adopt the right training methods, they will obtain the most favorable results. For example, a study of healthy middle-aged women athletes revealed that participation in exercise that produced an increased pulse rate for a minimum of 20 minutes was positively associated with the volume of medial tibial cartilage. None of the women in this study exhibited knee cartilage deficits as a result of this activity.

Additional Benefits of Active Aging

While chronic exercise is a known preventer and antidote to many of the problems that plague the sedentary aging population, there exist additional benefits that exercise brings to the aging population that are not often discussed in the literature.

Cancer

Recent research suggests that exercise can not only prevent cancer but also significantly reduce the risk of cancer-specific mortality in individuals who increase their levels of exercise postdiagnosis, specifically in breast and colorectal cancer. Adjusting for age at diagnosis, stage of the disease, state of residence, interval between diagnosis and physical activity assessment, BMI, menopausal status, hormone therapy, energy intake, education, family history, and treatment modality, researchers discovered that women who regularly participated in high levels of physical activity had a significantly greater chance of surviving breast cancer. Reduced mortality rates were also witnessed in women with Stages I to III colorectal cancer who participated in at least 18 metabolic-equivalent task hours of physical activity per week. Further research is necessary to evaluate this trend as related to other cancers as well as the precise amount of exercise necessary to obtain these benefits.

Cognitive Function

While many studies have investigated the benefits of active exercise for one's physical health, the benefits specific to cognitive function have received little recognition in comparison. This is staggering since declines in cognitive function have become one of the major contributors to the loss of independence in the aging population. Recent studies indicate that regular exercise can reduce reaction time and increase serum levels of testosterone and growth hormone in elderly men. These hormones are believed to exhibit a protective effect on the risk of dementia and Alzheimer disease. Associations between these diseases and low levels of physical activity were more distinct among carriers of particular genotypes. However, chronic exercise at midlife and beyond suggests an ability to delay the onset of dementia and Alzheimer disease despite genetic susceptibility. At present, Wright and colleagues are investigating the effects of chronic high-intensity exercise on specific areas of thought processing ability: working memory, sustained and selective attention time, response variability, nonverbal problem solving, and reaction time.

Depression

Depression is a common condition in the later life stages. Studies have shown that depression is most likely to emerge when an individual transitions from an active to a sedentary lifestyle. It is associated with the largest decrease in duration of physical activity. When mobility status was assessed, individuals who were able to maintain high levels of mobility throughout the aging process exhibited fewer depressive symptoms despite their decline in overall physical activity.

Diabetes

In recent years, Type 2 diabetes has emerged as one of the most rapidly growing public health concerns worldwide. It is well known that obesity, diet, and levels of physical activity combine with genetic factors to increase the risk of developing Type 2 diabetes. While all these factors contribute independently, obesity has been shown to be the largest contributor to the onset of the disease. Those with diabetes or at highest risk of developing the disease engage in rates of physical activity that are significantly below the national average, as determined by a nationally representative survey of the U.S. population conducted by the Medical Expenditure Panel Survey. Although genetics is an important contributing factor, it is important to note that it is only part of the problem and must usually be coupled with unhealthy lifestyle choices for the disorder to develop.

Stroke

Studies on the preventive benefits of physical activity for stroke revealed that increased activity levels are associated with a reduction in stroke mortality. Test subjects were assessed by self-reports of occupational and leisure activities. In addition, moderate levels of exercise exhibited benefits among individuals already diagnosed with heart conditions such as left ventricular hypertrophy.

It is of paramount importance for the senior population to maintain increased levels of physical activity if they wish to remain functionally independent throughout midlife and beyond. While there exist many age-related changes that we cannot avoid, exercise is a known preventer and antidote to the ravages of age-related disease. People everywhere are starting to realize these benefits as the number of individuals above 50 participating in high-level sports continues to increase. Records of the New York City Marathon from 1983 to 1999 reveal that the number of runners over the age of 50 is increasing more rapidly than is the number of any other age-group. In addition, the race times of the masters athlete group are demonstrating significantly greater improvement compared with the younger runners.

While injuries do occur within this masters athletes group, this is primarily because the athletes do not change their training regimens to accommodate the physiologic changes their bodies are experiencing. To avoid these changes and still participate in chronic high-level exercise, these athletes must FACE their future. FACE is an acronym for the four components of fitness after 40 that are essential to maximizing performance and training effectively:

F—*F*lexibility

A—*A*erobic exercise

C—"*C*arry a load," or resistance training

E—*E*quilibrium and balance

Creating a balanced workout that touches on these cornerstones of physical fitness is a smart way to achieve one's fitness goals. FACE applies not only to competitive athletes but also to people of all ages and activity levels. Those who adopt an exercise regimen that embodies all these components will be able to reduce the slowing phenomenon that is so often thought to accompany life after 40.

Future efforts should focus on raising awareness about the benefits of active aging and preserving the longevity of masters athletes. This way, more individuals will be able to enjoy functional independence and the benefits of a healthy lifestyle into their later years. This is becoming increasingly more important each day as the baby boomer generation is now in their 60s and is starting to transition to the age of senior citizens. Therefore, time is running out for physicians to intervene and encourage the sedentary individuals within this group to start exercising before they reach the age of reduced functional capacity.

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See also Arthritis; Benefits of Exercise and Sports; Shoulder Arthritis

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Sesamoiditis

The sesamoid bones of the foot were named because of their resemblance to sesame seeds. Unlike most bones, which are connected to each other through muscles and tendons, the two small sesamoid bones are found embedded in the muscle/tendon of the flexor hallucis longus muscle. Injury to these bones often occurs when great stresses are placed on the foot, such as in running and ballet dancing.

Anatomy

The flexor hallucis longus muscle is found on the undersurface (plantar surface) of the foot. It is responsible for flexing the great toe and is important in weight bearing and in transmitting forces through the foot, especially during push-off. The sesamoid bones act as a pulley for the muscle and, as such, allow much greater forces to be transmitted; a similar functional phenomenon elsewhere in the body is the kneecap (patella), which is also a sesamoid bone. The sesamoids also cushion and protect the joint where the big toe meets the foot (first metatarsalphalangeal joint).

Causes

Injury to the sesamoid bone/hallucis complex can occur as the result of a direct, acute injury or in a more chronic fashion, as in overuse or repetitive injuries. Either of the two sesamoid bones can be injured, but the medial sesamoid (closer to the inside of the foot or tibial side) is more commonly involved.

Fracture

Fracture of a sesamoid bone can occur as the result of a direct blow or forced hyperdorsiflexion (bending of the toe upward); alternatively, it can result from cumulative repetitive injury. A fracture results in immediate pain over the ball of the foot in the area underneath the great toe. There may or may not be swelling and bruising, and it may be difficult to bend or straighten the toe. Attempts at maintaining a normal gait will cause pain in this area of injury.

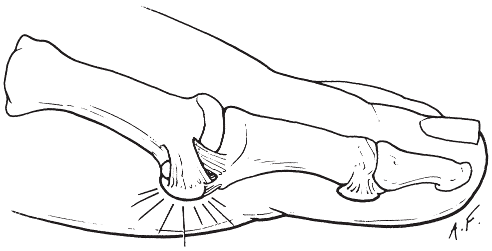

Figure 1 Sesamoiditis

Note: Sesamoiditis usually affects one or both of the sesamoid bones that lie within the tendon at the first metatarsalphalangeal joint.

Stress Fracture and Sesamoiditis

Not uncommonly, however, pain develops gradually in the same area and may be the result of a stress fracture or sesamoiditis. A stress fracture results from repetitive injury, often during a period of more intense or frequent training. In a stress fracture, the repetitive, frequent microtrauma to the bone overwhelms the bone's ability to heal itself. It occurs more frequently in ballet dancers and long-distance runners, for whom frequent, forceful toe-offs are necessary. Additionally, football players are at risk, especially when playing on artificial surfaces.

In a similar manner, irritation and inflammation of the bone and surrounding soft tissue structures—the muscle, tendon, and bursa, collectively called the sesamoid complex—can occur. This condition is called *sesamoiditis* (Figure 1).

Diagnosis

History and Exam

Evaluation of this type of injury can be performed by a health care provider comfortable with disorders in the foot and ankle. The patient's main complaint is pain under the first metatarsalphalangeal joint (the "ball of the foot"), which worsens with weight-bearing activity and is somewhat relieved with getting off the injured foot. A thorough history is often the key to diagnosis, especially in chronic injuries. In addition to the location and character of the pain, important clues on history include any changes in training (frequency, intensity, duration) and in the footwear and surface used by the athlete.

Examination of course focuses on the area of the sesamoid bone but should include a complete exam of the foot, ankle, and gait (if pain allows) to search for predisposing factors. Pain is often elicited in bending and straightening the toe, particularly bending the great toe upward. Tenderness is prominent in the area of the sesamoid bones.

Imaging

With acute and chronic injuries, X-rays can be helpful in making the diagnosis. Interestingly, the medial sesamoid is composed of two parts (bipartite) in about 11% of the population, and this sometimes makes the diagnosis of an acute fracture difficult. X-rays of the other foot are sometimes then done for comparison, or additional imaging may be necessary.

Management

Nonsurgical

Initial management of injuries generally includes activity and weight-bearing modification, in addition to relative rest, ice, and nonsteroidal anti-inflammatory medications such as ibuprofen. Treatment of an acute fracture may require immobilization and non–weight bearing for 3 to 4 weeks or longer, followed by the use of orthotics for the shoe and a slow, gradual return to activity.

A stress fracture may also require casting for a short period of time, but chronic injuries, including sesamoiditis and some stress fractures, are best treated by eliminating the repetitive stress that caused the injury. This may involve a period of rest from the aggravating activity and modification of the shoe with orthotics and inserts. These are designed to remove the stress from the sesamoid complex and may be a gel insert or J-shaped pads. A stiffer-soled shoe may also be helpful. Activities often need to be modified for at least 6 to 8 weeks. If painfree by 6 to 8 weeks, the athlete may then begin a gradual return to activity. It may take 3 to 6 months for symptoms to completely resolve in some cases of acute or chronic injury. Patients should continue to wear appropriate orthotics during this time and resume activity as tolerated.

In sesamoiditis, a diagnostic and therapeutic corticosteroid injection of the sesamoid complex may be beneficial, in addition to the previously mentioned management.

Surgical

If there is no improvement after 6 months, surgery may be considered to improve comfort and function. Surgery may be discussed as an earlier option for a highly competitive athlete who desires a chance to return to competition sooner.

If an acute fracture has not healed properly (nonunion), then curettage and grafting of the bone may be attempted. Pinning with screws may also be an option. If these are not viable options, or are unsuccessful, it may be necessary to remove the bone.

Excision of a sesamoid bone may also be indicated in refractory cases of sesamoiditis or a stress fracture. It is important for the surgeon to identify which sesamoid bone (medial or lateral) is the troublesome one as removal of both bones has often been found to result in a significant deformity of the joint connecting the great toe to the foot.

Postoperatively, the patient can expect to be in a non–weight bearing cast for at least several weeks. After this, weight bearing may begin gradually, with a total casting time of approximately 6 weeks. Once the cast is removed, additional orthotics for a longer period of time may be necessary as the patient progresses back to activity.

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See also Foot and Ankle Injuries, Surgery for; Foot Injuries; Orthotics; Podiatric Sports Medicines

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Sever Disease

Sever disease, also known as *calcaneal apophysitis,* was first described in the early 1900s. The calcaneal apophysis is a cartilaginous growth center located in the heel of the foot. Calcaneal apophysitis is a common cause of heel pain in growing, athletically active youth. Originally described as an inflammatory process, it has more recently been thought to result from overuse and weight-bearing injury to the growth center.

Anatomy

For descriptive purposes, the foot is divided into three areas: forefoot, midfoot, and hindfoot. The hindfoot contains two bones, the talus and the calcaneus. The calcaneus contains a vertically oriented C-shaped growth center located in the back of the heel. The growth center appears around age 5 to 9 and usually closes by age 13 to 16, when the calcaneus has achieved its mature adult shape. An additional cartilaginous growth center, the calcaneal ("traction") apophysis, is located where the Achilles tendon attaches to the bone.

Causes

Sever disease was originally described as an inflammatory process occurring within the calcaneal apophysis. Another proposed etiology was disruption of the blood supply to the growth center. Now, Sever disease is believed to be the result of repetitive mechanical stress applied to the apophysis by a tight heel cord (Achilles tendon) in an overactive young athlete.

This repetitive impact and shear stress on the growth center leads to microtrauma and injury at the junction of the bone and cartilage. This may occur during periods of rapid growth, such as a growth spurt, when the calf muscles and tendons cannot lengthen as quickly as long bones such as the tibia. An increased amount of athletic participation, including longer-duration, higher-intensity, and increased frequency of activities, contributes to the repetitive loading of the heel with weight-bearing activity. Sever disease does not occur after puberty, once the cartilage growth center fuses to become bone.

Symptoms

Sever disease is most common in active children 8 to 12 years old. It is slightly more predominant in boys. It presents with intermittent or daily heel pain and occurs on both feet in more than 50% of children. There is usually no history of an acute fall or direct injury to the heel. The child may describe the pain as located over the heel, and it may be severe enough to cause a limp, especially after participating in physical activity. While the pain may be present at rest or with daily activities such as walking, it is generally made worse with weight-bearing activities, such as running and jumping in sports activities. While all sports can make the symptoms of Sever disease worse, sports such as soccer, basketball, and running are common culprits. Heel pain may present at the beginning of a sports season or when the child is experiencing a growth spurt. The pain is usually absent in the morning, increases with activity during the day, and decreases with rest. Hard surfaces, such as a basketball court, or athletic shoes with little support and cushioning, such as soccer cleats, may worsen the symptoms.

Diagnosis

On physical examination, the most common finding is pain with compression of the inside and outside of the heel (the "squeeze test"). There should be no swelling, redness, or other skin or bone abnormalities. Usually, the gait is normal, but the child may walk with a limp. Many children also have a decreased flexibility or tightness of their calf muscles, resulting in limited dorsiflexion, the ability to pull or stretch a foot toward the head. The strength of the calf muscles is normal. Foot abnormalities such as pronation and flat feet may be present and worsen the condition. The child should otherwise be healthy, with no night pain or other signs or symptoms of systemic disease.

Plain radiographs are not routinely obtained because there are no findings that are diagnostic or specific for Sever disease. Findings such as irregularity of the growth center are often present on radiographs of asymptomatic feet. If the pain is unusual in character, other systemic symptoms are present, or the pain persists despite adequate rest and treatment, then plain radiographs may be considered to rule out other causes.

Treatment

The mainstay of treatment involves nonsurgical therapies. The most important treatment principle is to discontinue the repetitive activities that are causing the heel pain. This means completely avoiding or significantly limiting impact sports activities that involve running and jumping for some period of time.

The use of soft heel cups or heel lifts may help cushion and relieve the tension on the heel. Children should wear good-quality athletic shoes with an adequate shock-absorbent sole and avoid going barefoot at all times. Therapeutic exercises, such as stretching and strengthening of the calf muscles, may be prescribed under the supervision of a physical therapist.

As Sever disease is not an inflammatory process, anti-inflammatory medications are not indicated to decrease inflammation. Application of ice and the use of medications such as acetaminophen or ibuprofen may be helpful in reducing pain. Corticosteroid injections are not recommended. In rare cases, when the pain is severe and accompanied by a limp, crutches or immobilization may be used for a short period of time.

The majority of children are painfree and able to return to the desired physical activities within weeks to 2 months of proper treatment. A return to sports and physical activity is appropriate when the child can participate with minimal discomfort. Continued stretching, especially during growth spurts, may prevent initial or recurrent Sever disease. There are no known long-term sequelae of Sever disease.

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See also Apophysitis; Foot Injuries; Osgood-Schlatter Disease; Sports Injuries, Overuse

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Shift Work and Exercise

Approximately 3.6 million people in the United Kingdom work mostly on shifts, representing 14% of the British workforce. This proportion is similar in most other developed countries. Shift workers predominate in heavy industries and emergency services, but they are also increasingly found in finance and service industries. Data from epidemiological studies suggest that shift work, and especially night work, is associated with insomnia, gastrointestinal problems, obesity, heart disease, and cancer. Disruption of circadian rhythms during shift work is thought to be important in explaining these increased health problems. Nevertheless, the differences between shift workers and day workers in lifestyle factors, including participation in physical activities, have been generally underresearched.

On a behavioral level, shift work can restrict the opportunities to be physically active, although this can depend on individual choice of leisure pursuit (group or individual based). On a biological level, the disruptions to circadian rhythms and sleep that are associated with shift work can alter the normal physiological responses to a bout of physical activity as well as how well a particular exercise bout is tolerated. The latter issue might have implications for long-term adherence to physical activity regimens during shift work. Unfortunately, studies in which physical activity interventions are administered to shift workers are rare.

Physical Activity Behaviors During Shift Work

Workers and their families can alter their habits to cope with the disruption to domestic life that is associated with shift work, although women shift workers seem to have particular problems in balancing their work and domestic lives. Unlike the malleable domestic environment, organized leisure activities and training sessions for sports clubs are generally scheduled in the early evening and weekends to accommodate the day-working majority. This scheduling conflict makes it very difficult for the shift worker to participate in organized activities and has been found to contribute to the decision of some people to leave shift work altogether. Those shift workers who enjoy solitary or individual activities are probably not so disadvantaged. Individual shift workers who join fitness and health clubs can enjoy the benefits of "off-peak" membership costs and can use the facilities at less crowded times. Activities such as cycling, swimming, and jogging can also be carried out on an individual basis in the shift worker's own spare time. Nevertheless, organized competitions in these sports are still normally scheduled in the weekend, when it is more likely that a shift worker is at work. Moreover, the transient negative experiences of exercising while partially deprived of sleep and at times that are out of kilter with the "body clock" (e.g., in the early morning) might be perceived to be significant enough for the shift worker to stop these individual activities. Such attrition at an early stage in an exercise program would be unfortunate since there are, as discussed below, likely benefits of exercise to the shift worker.

Benefits of Physical Activity to the Shift Worker

Physical activity, when timed appropriately, may consolidate human circadian rhythms. Although purely correlational in nature, there is evidence that good tolerance to rapidly rotating shift work is associated with large amplitudes (mean-to-peak differences) of circadian rhythms, which tend to be observed more in physically active and fitter individuals than in sedentary people. Nevertheless, it may well be that those people who are naturally more tolerant of shift work are able to be more physically active, rather than vice versa. This "chicken or the egg" conundrum is common in many descriptive studies on shift work. There is no direct evidence to suggest that any unique circadian characteristics of physically fit shift workers mediate fewer short-term tolerance problems and better health compared with less fit workers.

It is known that habitual bouts of physical activity increase both the duration and the quality of nocturnal sleep in diurnally active people. The amount of slow-wave sleep (SWS), which is thought to be important for brain restoration and recovery during nocturnal sleep, is also increased by physical activity. It is possible that physical activity is beneficial via a reduction of anxiety, a sleep-inducing thermogenic effect, or long-term antidepressant effects or by mediating a circadian phase that is more amenable for sleep. Increases in sleep quality following exercise may be mediated by temperature elevation, which, in turn, increases SWS. Chronic physical activity promotes the sleep-onset process by inducing more proficient temperature downregulation. In a recent study on the effects of exercise on daytime sleep during partial sleep deprivation, it was found that sleep latency (the time it takes to enter sleep after retiring to bed) and wrist activity were reduced by exercise taken 4 hours prior to the sleep period, offering support that the favorable effects of physical activity on sleep quality translate to a shift work context. Nevertheless, shift workers who are motivated enough to exercise might attempt to exercise closer than 4 hours to a given sleep period or even at night. The exact consequences of these unusual timings of exercise bouts relative to the unusual timings of sleep periods are not known. Recently, it was found that there are no negative effects of exercise when taken close (within 2 hours) to the start of a sleep period, although this sleep period was taken at night by people living diurnally.

The temporal placement of physical activity may also affect the adjustment to shift or night work via advancing or delaying an individual's circadian rhythms. If circadian rhythms can be adjusted to times more amenable to the particular shift that is being worked, it is possible that feelings of fatigue, tiredness, sleepiness, and other short-term effects of working unusual hours can be attenuated. These improvements in shorter-term tolerance might, in turn, make exercise more tolerable to the shift worker and so aid the maintenance of participation in physical activity regimens. Nocturnal exercise can induce phase delays in the onset of melatonin secretion, but exercise-induced phase advances have not been confirmed in humans. At best, the phase-shifting effects of exercise on the body temperature rhythm are very small, and the substantial levels of activity (possibly 3 hours of exercise at 50% to 60% of maximal oxygen uptake) needed to obtain these small phase shifts are impracticable and may even be unattainable by the majority of shift workers.

Physical Activity Interventions During Shift Work

It has been speculated that improved workplace-based recreational facilities, to promote physical activity, might be useful for general tolerance to shift work. Nevertheless, there is little empirical support for such views. To date, there has been only one study in which a physical training intervention was administered specifically to shift workers. Mikko Härmä, and his colleagues in Finland, designed a training program for 119 women shift workers. Exercise sessions were administered between two and six times per week, between 60% and 70% of maximal heart rate, and for a 4-month period. It was found that this moderate physical training mostly benefited aspects of sleep. General fatigue decreased significantly in the training group during the whole cycle of rotating shift work, and scores on some tests of performance improved. The authors suggested that moderate exercise should be performed several hours before the main sleep period when on a morning or day shift schedule. Physical activity was advised before an evening nap, during a period of night work, although the researchers did not investigate the specific issues about the timing of the exercise.

Although there are predicted benefits of physical activity for the shift worker, there is evidence that the majority of shift workers do not follow the general guidelines to take more exercise. Whether this is due to the disruptive nature of shift work, feelings that an unhealthy lifestyle is acceptable providing that shift work continues to pay well, or the general reluctance to adopt a healthy lifestyle is, at present, unclear.

Greg Atkinson

Author's Note: The author's research work on shift work and health is currently funded by the National Prevention Research Initiative: http://www.npri.org.uk.

See also Seasonal Rhythms and Exercise; Sleep and Exercise; Sleep Loss, Effects on Athletic Performance

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Shoulder Arthritis

Glenohumeral arthritis, or shoulder arthritis, is a rare but potentially debilitating condition in the young athlete. A number of treatment options are available, depending on the etiology of the condition, the extent of joint damage, and the functional deficit present.

Etiology

Degenerative arthritis can be classified as either primary, implying an unknown causative agent, or secondary, in which the underlying pathological mechanism has been established. Primary osteoarthritis is primarily an age-related disorder associated with repetitive stress on a normal joint. Athletes most at risk include those engaged in repetitive overhead activities, such as in cricket, baseball, weight lifting, and racquet sports. In contrast, secondary arthritis, which is more common in the younger athlete, usually has an underlying cause, such as a previous shoulder surgery, trauma, infection, ischemia, or inflammation. Capsulorraphy arthropathy can occur if the anterior shoulder capsule has been excessively tightened during stabilization surgery, thereby limiting movement, principally external rotation. Posterior translation during external rotation results in posterior glenoid erosion and capsular damage. Osteonecrosis (avascular necrosis) may be traumatic or atraumatic in origin. In traumatic cases, there is usually disruption of the vascular supply to the humeral head following a proximal humeral fracture. Atraumatic osteonecrosis may be idiopathic or secondary, resulting from smoking, steroid and alcohol use, or hematological disorders (sickle cell anemia and thalassemia). The patients are normally younger and may present with few diagnostic indicators besides pain. Inflammatory arthritides such as gout, systemic lupus erythematosus (SLE), psoriatic arthritis, and ankylosing spondylitis, though less common in athletes, form the second largest category of glenohumeral arthritis. In these conditions, multiple joints may be involved. Clinical findings of cervical spine pathology, the presence of a cuff tear, or bilateral glenohumeral involvement should prompt further hematological investigation. Glenohumeral septic arthritis is uncommon except in immunocompromised individuals. Localized erythema and warmth are highly suggestive of infection, and if confirmed by aspiration, urgent arthroscopic irrigation and debridement is required.

Assessment of the Arthritic Shoulder

A patient with glenohumeral arthritis usually presents with a history of progressive pain and stiffness. The pain commonly intensifies with use and interferes with sleep, especially when lying on one side. There may be crepitus on glenohumeral movement and an inability to perform tasks requiring shoulder rotation. Specific consideration must be given to symptoms and signs suggesting the possible underlying etiology. Initial examination of the shoulder should include inspection of the upper torso for signs of muscle atrophy and asymmetry. Careful assessment of the cervical spine is mandatory to identify sources of referred pain. The active and passive ranges of shoulder motion must be recorded. Examination usually reveals pain with a restricted range of movement, often accompanied by crepitus. Limited external rotation is a common finding in osteoarthritis and may require adjunctive therapy. The integrity and strength of the rotator cuff muscles should be assessed as this may influence the choice of treatment offered. This may, however, be difficult due to pain. Unlike in rheumatoid arthritis, most patients with osteoarthritis have preserved or only slightly diminished strength, indicating only mild, if any, rotator cuff dysfunction. It is also important during the assessment process to ascertain the nature of the sport played by the athlete, hand dominance, level of performance, and intention to return to competition.

Imaging the Arthritic Shoulder

The three preferred radiographic projections of the glenohumeral joint are a true anteroposterior view, a scapular outlet view, and an axillary view. The radiographic features of glenohumeral osteoarthritis typically include joint space narrowing, osteophyte formation, subchondral sclerosis, and cyst formation. Further imaging modalities are not always necessary, but computed tomography (CT) may be a useful aid in preoperative planning to assess the patient's bone stock and glenoid version. Magnetic resonance imaging (MRI) may be indicated when there is clinical suspicion of a rotator cuff tear, which may influence future management: For example, a major tear may rule out total shoulder replacement.

Conservative Treatment

There is wide variability in the presentation of degenerative glenohumeral disease. Significant destructive radiographic changes may be present, but an individual may continue to function well if his or her demands are low. On the other hand, individuals with limited radiographic findings may find themselves substantially incapacitated by pain. Given this inconsistency, the success of nonoperative therapy cannot be based on radiological findings but rather must be based on the patient's own views of his or her functional capabilities. Recognizing that the most common arthritides are progressive in nature, conservative management should be based on maintenance of function as well as improvement. The principles of conservative management in glenohumeral osteoarthritis include: (a) activity modification, (b) medication for pain relief, and (c) a self-conducted physiotherapy program. Activity modification requires a commonsense approach, whereby the patient limits its symptom-provoking activity. Activities such as racquet sports should be discouraged unless they are tolerable to the patient. This may seem a simple request; however, with such a large emphasis on continued participation in sports, many athletes are unwilling to forego playing despite the pain. The success of drug therapy in treating osteoarthritis is variable. Nonsteroidal anti-inflammatory drugs (NSAIDs) are often given to relieve symptomatic pain, but there is no evidence of its having any affect on disease progression. It is widely suggested that opiates should be avoided due to their potential for dependence. Omega 3 and glucosamine supplementation may be beneficial, although data regarding their efficacy are scarce despite widespread over-the-counter use. Intraarticular corticosteroid injections may provide temporary symptomatic relief in recalcitrant cases. Repeated injections are discouraged due to their catabolic effect on articular tissue and, therefore, should not be used as a mainstay of treatment. Intraarticular hyaluronan injections, although more costly, have been shown to have longer beneficial effects compared with corticosteroids, with fewer side effects. Physiotherapy typically involves gentle range-of-movement exercises to preserve and, if possible, improve joint motion, strengthen the rotator cuff muscles, and maintain glenohumeral stability.

Arthroscopic Treatment

Arthroscopic debridement may be employed to treat early glenohumeral osteoarthritis that has failed to respond to conservative management. Arthroscopy allows careful examination of the degree of cartilage damage and the integrity of the soft tissue envelope. Unstable chondral fragments and osteophytes can be removed and microfracture performed to stimulate cartilage regeneration. Associated pathology can be addressed by additional procedures such as the repair of labral/rotator cuff tears, subacromial decompression, or acromioclavicular joint resection. Arthroscopic debridement is principally a temporary treatment measure for shoulder arthritis, and its results depend greatly on the severity of the disease. It is however, a valid option for younger athletic patients, in whom more definitive procedures such as arthroplasty may be contraindicated due to the risk of component deterioration and subsequent failure.

Shoulder Arthroplasty

The principle indication for glenohumeral arthroplasty (joint replacement) is pain refractory to conservative and arthroscopic treatment. The procedure offers reliable pain relief and may result in secondary recovery of strength and function. Arthroplasty should be considered with caution in mild to moderate arthritis, in younger patients with high functional demands, and where there is a lack of glenoid bone stock or rotator cuff deficiency. It is important when counseling a patient with regard to prosthetic reconstruction that realistic expectations be set. The type of arthroplasty chosen must take into account patient factors such as age and activity levels, as well as the nature of the underlying pathological process, the pattern of joint destruction, and the integrity of the soft tissue envelope. Choices include humeral head resurfacing (total or partial), stemmed hemiarthroplasty, and total shoulder replacement (including reverse polarity). Where good bone quality remains, humeral head resurfacing using a pegged metal cap is a relatively simple technique providing a valid alternative to stemmed hemiarthroplasty, particularly in younger patients. This form of surgery is less invasive than traditional shoulder replacement and, therefore, recovery is typically much faster. Resurfacing can help prolong or avoid altogether the need for future joint replacement. It is therefore an attractive option for young athletes in whom undergoing arthroplasty at an early age carries a greater risk of future revision surgery. More normal anatomical relationships are maintained; potential errors in determining the humeral head height, glenoid version, and implant alignment are minimized; and stem-related complications are avoided.

Glenohumeral Arthrodesis

This is a fairly crude technique involving fusion of the humeral head to the glenoid and acromion, thereby relying solely on scapulothoracic rotation to move the upper limb. It is now rarely employed as cases unsuitable for modern replacement techniques are limited. Indications include severe septic arthritis and previous failed joint reconstruction with severe bone loss. Patients undergoing this type of procedure generally have significant functional limitation.

Conclusion

In the active individual, most cases of glenohumeral arthritis should be managed using the conservative methods detailed above. Once these are exhausted, surgical treatment must be selected on a case-by-case basis, considering the individuals functional demands, type and severity of arthritis, and residual bone stock. Patients with only minor arthritic changes may benefit from arthroscopic treatment initially, whereas those with extensive damage may require total arthroplasty. In these cases, where possible, less invasive techniques such as cementless resurfacing of the glenoid should be employed. Further long-term randomized studies are required to compare cementless humeral head arthroplasty with stemmed hemiarthroplasty and total shoulder arthroplasty if a conclusion about the optimal treatment of young arthritic athletes is to be reached.

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See also Arthritis; Shoulder Injuries

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Shoulder Bursitis

Bursae are flattish, fluid-filled sacs lined with synovial membrane that typically lie between bone and tendons or adjacent tendons; bursa sacs provide a smooth gliding surface for tendons to move along and may lessen the irritating friction that could otherwise occur between the tendon and other structures. At baseline, the fluid in the bursa is minimal. When the bursa becomes inflamed (as indicated by the suffix "itis"), it enlarges and the fluid contents increase. There are eight bursae in the shoulder. The primary or largest bursa, the subacromial bursa, is located just under the acromion, the rounded-off bony prominence located most laterally on the shoulder. While understanding the concept of *shoulder bursitis* is useful, it may not completely describe the root cause of the problem. The inflamed bursitis condition commonly occurs due to or in response to rotator cuff tendon inflammation from poor mechanics and/or overuse. The rotator cuff muscles are anatomically directly underneath the subacromial bursa; when one structure is inflamed, the adjacent structure becomes inflamed as well (Figure 1).

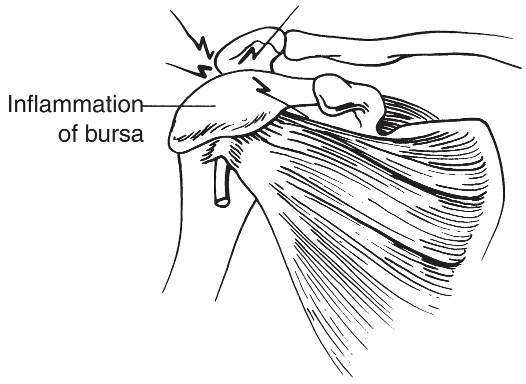

Figure 1 Inflammation of the Bursa Occurs Between the Rotator Cuff Tendons and the Shoulder Blade

Causes

When the bursa becomes inflamed, it swells up and occupies more space. In doing so, the swollen bursa can further limit the size of the space (the subacromial space) in which the rotator cuff tendon moves. In certain extremes of motion, this can cause a painful impingement phenomenon. This mechanism can lead to further irritation and pain. Rotator cuff tendinopathy may often be the underlying mechanism causing shoulder bursitis. The rotator cuff muscles, which become tendons when attached to bones, are the dynamic structures that allow for the tremendous range of motions in multidirections that the shoulder is capable of producing. There are four muscles that make up the rotator cuff: supraspinatus, infraspinatus, teres minor, and subscapularis. The shoulder is referred to as a ball-and-socket joint—the rounded ball of the humerus fits into the shallow, saucer-like socket of the glenoid. A golf ball resting on a tee is an appropriate analogy. This great mobility of the shoulder joint does come at a price, with the shoulder joint having increased susceptibility to injury and overuse.

Clinical Evaluation

Rotator cuff problems generally occur in older populations, ages 40 to 50, who may or may not be athletically inclined. It can present either insidiously, which may or may not involve an increase in certain shoulder movement activities, or in a more acute setting after a specific injury. Any change in the intensity, frequency, or duration of an activity, be it at work or at home, as well as any new activity could contribute to developing an overuse injury. Age-related changes to tendons result in their less pliable or elastic (rubber band–like) quality; this can lead to fraying, swelling in the tendon, calcified deposits, and frank tears. Thus, as we get older, we may be more prone to overuse injuries such as rotator cuff tendinopathy and shoulder bursitis, and unfortunately, we may recover less well from them.

In the athletic population, rotator cuff tendinopathy can develop in any overhead throwing or motion sport such as baseball and softball, racquet sports such as badminton and tennis, swimming, and water polo.

Examples of activities that patients describe are a weekend playing softball or playing fetch with a dog and carrying more than the usual bags of groceries or heavy suitcases on a trip. Occasionally, they may recall a specific incident, such as a fall on an outstretched hand or a sudden jerking or traction from catching a heavy falling object. Most of the time, however, a patient cannot say how the pain started.

Most commonly, the pain affects a fairly large area, directly over the shoulder, in the posterior neck/upper back, and, not uncommonly, down the arm over the deltoid region. Rarely does shoulder bursitis pain radiate past the elbow. The pain or soreness is not only exacerbated by heavy lifting or very strenuous activities, but it can also result from simple maneuvers performed in activities of daily living. This would include reaching up into a cabinet, lifting an arm up to the head to brush or shampoo one's hair, reaching behind to slip a hand into a jacket sleeve, pulling up a pair of pants, and turning a steering wheel, to name some of the most common exacerbating actions.

One common symptom of rotator cuff tendinopathy is nighttime pain that occurs with lying on the affected arm/shoulder. It can wake a person up if he or she should unintentionally roll over to that side. Usually, the "weakness" patients may have is the result of guarding against the pain, which would reflexively limit how much load they place on the shoulder. This is in contrast to any inherent or primary loss of muscle strength, intrinsic to the muscles or nerves itself.

Management

Rehabilitation

The mainstay of treatment for rotator cuff tendinopathy/shoulder bursitis is effective physical therapy/rehabilitation. Initial exercises would involve stretching, correcting muscle imbalance and improving coordination, and eventually strengthening of the rotator cuff muscles. For athletes, an evaluation of biomechanics and the entire kinetic chain function, as well as pinpointing of training errors, should be incorporated to prevent recurrence of problems.

Medication

For pain relief, nonsteroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen or naproxen are often prescribed. There is some evidence to suggest that NSAIDs may slow or harm the healing process in tendons; additionally, care must be taken to prevent gastritis/stomach ulcers. Liberal application of ice for 15 to 20 minutes three times a day is recommended for pain control without the risk of any significant adverse effects. An option for pain control, especially pain causing significant disruption in sleep or work, is a cortisone injection. An advantage of corticosteroid injection is that pain reduction may allow the patient to participate in physical therapy more effectively. Cortisone is a powerful anti-inflammatory and can be injected directly into the affected joint or area—for example, directly into the inflamed subacromial bursa.

Imaging

For diagnostic purposes, imaging can be obtained. Although plain films or X-rays will not show bursitis or rotator cuff tendons, they are helpful to look for bony abnormalities that are indirect signs of rotator cuff problems, such as calcifications in the tendon, down-sloping or hooked acromion, and other bony processes that can cause similar symptoms such as arthritis. If more advanced imaging is desired, either because a frank and complete tear is suspected and/or the patient is not improving or the diagnostic picture is more complicated, magnetic resonance imaging (MRI) can be considered. MRI is the imaging modality of choice to directly visualize and evaluate the rotator cuff tendons. The presence of a complete tear is not an automatic indication for surgery, as many patients do quite well with a course of aggressive rehabilitation and there are people with rotator cuff tears who have good range of motion, have good strength, and are functionally asymptomatic.

Operative

Operative treatments can be considered if there is no progress, unrelenting pain, or inadequate function. Most rotator cuff tendon surgeries can be done with arthroscopy, whereby small incisions and thin pencil-like instruments are used, and most often on an outpatient basis.

Calcific Bursitis

On occasion, calcium crystals may accrue in the bursa. This "calcific bursitis" can be very painful and subject to flare-up of severe pain. Surgery is sometimes required to remove the calcified bursa.

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Shoulder Dislocation

The shoulder is the most frequently dislocated joint, and the injury is common in contact sports and activities with a potential for falling accidents, such as skiing or biking. It occurs commonly in young adults and can lead to significant disability for an athlete. Most dislocations result from trauma, and the majority (>90%) occur anteriorly.

Anatomy

The shoulder is a ball-and-socket joint. The humeral head (ball) sits in the glenoid (socket) and allows the large range of motion that humans have at the shoulder. This range of motion allows extremes of motion, such as those that an elite pitcher uses to throw the ball.

There are a number of structures that help stabilize the glenohumeral joint. First, to help the humeral head fit more snugly in the glenoid, the glenoid is surrounded by a ring of cartilage called the labrum. Second, the glenohumeral ligaments add further stability to the joint. These ligaments are thickened areas of the shoulder capsule, which encompasses the entire joint. Both the labrum and the glenohumeral ligaments can be injured when the humeral head dislocates out of the glenoid.

In addition, important arteries and nerves travel in this area and can be injured from a shoulder dislocation.

Causes

As mentioned, more than 90% of traumatic shoulder dislocations are anterior, with the head of the humerus dislocating out of the front of the glenoid. This usually occurs as the result of a fall with the arm in the abducted (held away from the body) and externally rotated position or when the arm is hit from the front when held in this same position, as can happen in a football tackle.

Less frequently (2–4%), the dislocation is posterior, with the humeral head dislocating out of the back of the joint. This usually occurs when the arm is forward elevated and internally rotated. These dislocations are less likely to occur from sports (although they can occur with the pass block in football) and are more likely the result of a motor vehicle accident, seizure, or electric shock (Figure 1).

Symptoms

The patient with an acutely dislocated shoulder is usually in a good deal of distress. He or she holds the arm slightly away from the body and in internal rotation. The patient avoids moving the joint due to the pain, and on examination, it will be found that there is little ability to rotate the shoulder.

If the patient has had previous shoulder dislocations, he or she may present without an acute dislocation but with complaints of the shoulder "popping in and out," especially when his or her arm is in the throwing position.

Diagnosis

In the acute setting, the history of the mechanism of the injury, as well as the physical exam, is usually enough to make the diagnosis. The examiner should always perform a good neurovascular exam (checking the pulses and nerve supply to the arm both in the central and peripheral distribution) as damage may have been done to important structures. The axillary nerve, which supplies the large deltoid muscle of the shoulder, is not uncommonly damaged from a shoulder dislocation. Axillary nerve integrity can be assessed by testing the sensation of the skin over the deltoid muscle on the outside of the arm.

It is also necessary to obtain X-rays to confirm the dislocation and the direction of the dislocation and to evaluate for other bony abnormalities such as fractures. Two specific fractures are commonly associated with a shoulder dislocation. A Hill-Sachs lesion is an impaction fracture of the back of the humeral head, and a bony Bankart lesion occurs when the labrum at the front of the glenoid is disrupted and pulls off a piece of bone. At least two views, and preferably three different views, of the shoulder should be obtained and are usually sufficient to make the diagnosis.

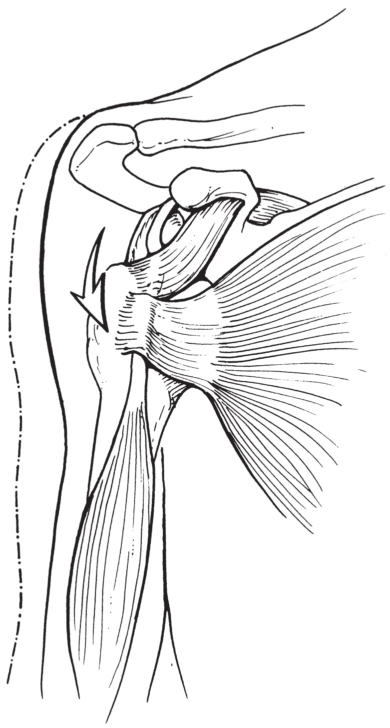

Figure 1 Shoulder Dislocation

Notes: Shoulder dislocations are relatively common because of the structure of the shoulder joint, which gives it great mobility. Unlike other joints in the body, the socket has almost no bony support, making it susceptible to injury in sports.

Management

Reduction

There are many different methods of reducing the dislocated shoulder (putting it back in place). The reduction is much easier to do if performed within a few minutes of the injury. After 15 to 30 minutes or so, muscle spasms and swelling make the reduction more difficult and painful and may necessitate patient sedation. Because of this, some providers may choose to forego X-rays (after ensuring a normal neurovascular exam) and attempt the reduction on the sidelines. This is especially true if the dislocation is a recurrence for the athlete.

Various reduction techniques can be done with the patient sitting or lying on his or her back and stomach. All methods use a countertraction force along the arm to help get the humeral head back over the glenoid rim. A simple method involves the patient lying on a table face down with the affected arm dangling off the side. A weight is tied to the arm to apply the force needed over time. Other methods involve the physician pulling gently downward on the arm while an assistant pulls upward on a sheet or towel wrapped around the patient's chest and under the armpit. As the shoulder relocates, a clunk may be felt.

Postreduction Care

After reduction, it is imperative to reassess the blood and nerve supply to the arm. X-rays should be taken to document that the reduction was successful and to assess for any bony abnormality in the setting of a first-time acute shoulder dislocation. A sling can be provided for the patient's comfort as well as to let the capsule and ligaments heal, especially if this is the first dislocation. For recurrent dislocations, the sling can be used as long as symptoms persist. The patient should be instructed in and begin early range-of-motion exercises, such as pendulum swings, to prevent shoulder stiffness and to allow a quicker return to function.

Rehabilitation after shoulder dislocation involves achieving range of motion and strengthening the muscles of the shoulder, in particular the rotator cuff and scapular stabilizers. These muscles help stabilize and support the shoulder joint.

Bracing may be used in athletes to protect them from the "at-risk" position of abduction and external rotation. There are a variety of braces on the market available to the athlete, all of which attempt to keep the arm from finding that at-risk position.

Surgery

Controversy exists regarding surgical correction of first-time dislocations. The statistics show that in young patients under the age 20, the rate of recurrence is 65% to 95%. In 20- to 40-year-olds, the rate is 60%, and above 40, only 10% will recur. This has led some to encourage young, active patients to consider surgical correction after the initial dislocation. The complications of recurrent dislocation include neurovascular injury, fracture, and degenerative arthritis of the shoulder joint.

Various surgical procedures for shoulder stabilization exist and can be performed open or arthroscopically. Open procedures use a large incision through which the surgery is performed, while arthroscopic surgery involves several small incisions made around the shoulder, with an arthroscope, or camera, used to visualize the shoulder joint.

Procedures to correct the unstable shoulder involve reattaching the torn ligaments and labrum and often eliminating any capsular redundancy. Unfortunately, sometimes a loss of external rotation of the shoulder results from the surgery. This can be detrimental to certain athletes, such as pitchers, who rely on excessive external rotation for their sport. The success rates for the two procedures are about equal now, with recurrence rates after surgery of 5% to 15%. The arthroscopic method affords less morbidity and the ability to see more of the joint itself.

Postoperative care involves a period of immobilization with a rapid introduction of range-of-motion exercises to prevent stiffness. As with nonoperative management, once painfree range of motion is achieved, gradual strengthening exercises are added.

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See also Shoulder Injuries; Shoulder Injuries, Surgery for; Shoulder Instability; Shoulder Subluxation

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Shoulder Impingement Syndrome

Shoulder impingement syndrome is a common source of shoulder pain in the general population as well as in the athletic community. Like other syndromes, shoulder impingement syndrome refers to a group of symptoms and diagnostic signs. As the name implies, this syndrome is caused by the compression of structures within the shoulder joint.

Athletic participation that requires overhead arm motion puts an athlete at risk for developing shoulder impingement syndrome. These sports include swimming, tennis, baseball, golf, volleyball, and gymnastics. In addition to overhead activity, a "loose" shoulder joint, the anatomy of the acromion, and disease within the acromioclavicular joint place an athlete at risk of developing this syndrome.

Anatomy

The shoulder joint is a very complex joint, with many structures. A good knowledge of the anatomy of this joint is essential for understanding shoulder impingement syndrome (Figure 1). There are two joints to be aware of, the *glenohumeral joint* and the *acromioclavicular joint.* The glenohumeral joint is composed of the glenoid fossa (socket) of the scapula (wing bone) and the head of the humerus bone (upper arm bone). The

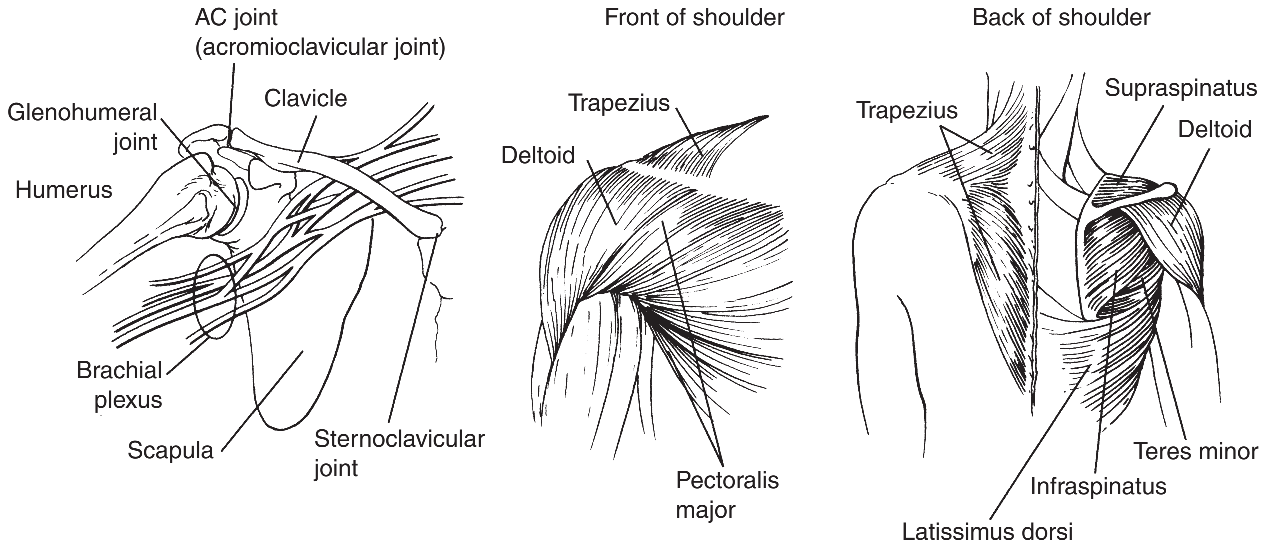


Figure 1 Anatomical Structures of the Shoulder

acromioclavicular joint is formed by the attachment of the outer part of the clavicle and the acromion process, a forward projection of the scapula.

Surrounding these bones are multiple tendons, ligaments, and muscles. More specifically, though, the following are anatomical structures important to a discussion of shoulder impingement syndrome: the rotator cuff complex (made up of four muscle-tendon units, the supraspinatus, infraspinatus, teres minor, and subscapularis), the subacromial bursa (a sac of fluid that lies underneath the acromion process), the labrum (a ring of cartilage in the glenohumeral joint), and the biceps tendon. All these structures may be internally compressed, causing shoulder impingement syndrome.

As mentioned, the anatomy of the acromion process has a role in causing shoulder impingement syndrome. This relationship was first noted by Dr. Charles Neer in 1972 in the *Journal of Bone and Joint Surgery*. He described three acromion types: Type I, flat; Type II, curved; and Type III, hooked (Figure 2).

Causes

Shoulder impingement syndrome is caused by the compression of structures surrounding the glenohumeral joint. Any source of weakness or dysfunction of the joint will result in instability and excessive motion of the humeral head. Surrounding the humeral head is the rotator cuff complex, together with the subacromial bursa. These structures are typically the ones impinged on. Compression commonly occurs between the humeral head and the acromion. A Type III, hooked acromion is mostly associated with shoulder impingement, but it may occur with any type of acromion morphology. Other structures in the shoulder may be the source of compression besides the acromion, however, and include the acromioclavicular joint as well as structures surrounding the coracoid process, another forward projection of the scapula.

Throwing athletes (baseball pitchers, javelin throwers, football quarterbacks) are at increased risk for shoulder impingement syndrome due to the extreme range of motion that is required of the shoulder to participate in their positions. The range of motion that places these athletes at risk is referred to as the “cocked position.” The cocked position is the point at which the athlete’s arm is maximally rotated overhead and extended behind the body. With the arm in this position, the stability of the shoulder is maximally stressed, causing excessive motion at the glenohumeral joint and subsequent compression of internal structures. Participation in these sports requires repetitive throwing motions, which may cause fatigue, weakness, and additional dysfunction of the glenohumeral joint, resulting in worsened compression and more severe impingement.

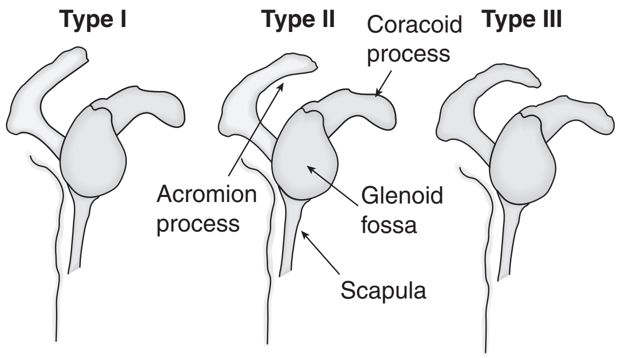
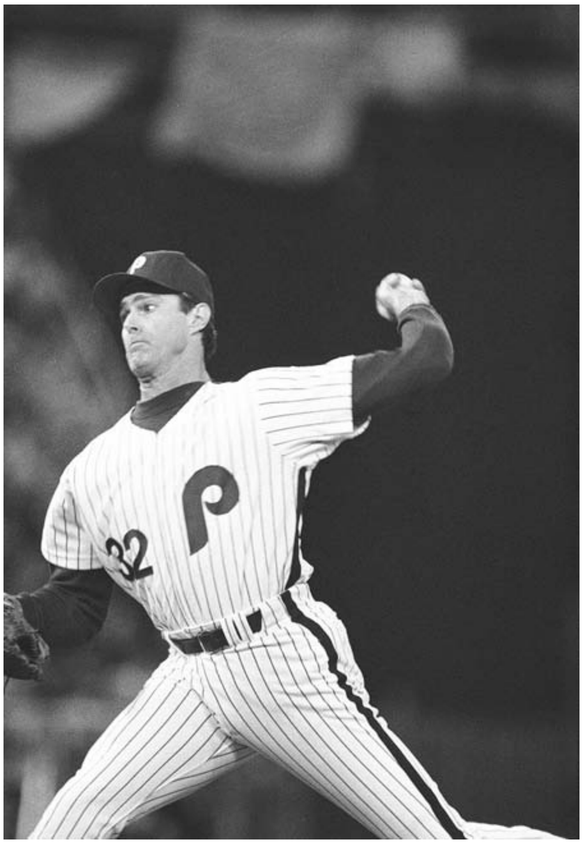


Figure 2 Anatomical Variants of the Acromion Process

Source: Adapted from Fongemie AE, Buss DD, Rolnick SJ. Management of shoulder impingement syndrome and rotator cuff tears [Figure 2m]. *Am Fam Physician.* 1998;57(4):667–674.



Cocked position for throwing. Philadelphia Phillies pitcher Steve Carlton delivers a pitch in the early innings of a World Series game against the Baltimore Orioles, Friday, Oct. 14, 1983, Philadelphia, Pennsylvania.

Source: AP.

Symptoms

Pain with overhead activity is the most common complaint. As the impingement worsens, pain is present outside activity and is typically located along the outside or back of the shoulder and occurs at night, especially when the patient lies on the affected shoulder. In addition to sports activities, the athlete may complain of pain when putting on a shirt or brushing his or her hair.

Initially, throwing athletes complain of increased stiffness in the shoulder and have difficulty with their warm-up activities. The pain is worse during the cocked position of throwing, as described above.

Diagnosis

As with all sports injuries, a diagnosis of shoulder impingement syndrome requires a thorough review of the history of the athlete's pain and an extensive physical exam. The physical exam starts with a thorough neck exam to make sure that a neck abnormality is not the cause of the shoulder pain. At the start of the shoulder exam, the athlete is asked to move the shoulder through all ranges of motion, looking for abnormalities or pain. If shoulder impingement syndrome is present, the athlete will have pain with movement and in particular when bringing his or her arm over the head, a motion commonly referred to as the "painful arc." Sometimes, with shoulder pain, strength can be diminished compared with the uninjured shoulder. However, in athletes, strength is typically preserved. Other special tests can be used to diagnose the presence of impingement on exam: These include a positive Neer test, Hawkins-Kennedy test, or Yocum test. The Neer, Hawkins-Kennedy, and Yocum tests attempt to cause external compression of internal shoulder structures, re-creating the athlete's pain. In a throwing athlete, pain can also be re-induced by moving the athlete's arm into an extended and rotated position, re-creating the cocked position of throwing. Reproduction of the troublesome pain is consistent with a diagnosis of a type of impingement called *posterior impingement*.

Plain radiographs (X-rays) may be obtained to look for bony abnormalities causing internal compression of shoulder structures. Radiographs will demonstrate the shape of the acromion as well as abnormalities in the acromioclavicular joint and coracoid process. All these, as mentioned above, can be a source of impingement, and their presence on X-rays makes a diagnosis of impingement for an athlete with shoulder pain more likely.

In addition to X-rays, additional imaging techniques may be used to diagnose shoulder impingement syndrome. Magnetic resonance imaging (MRI) is commonly used. In an athlete with shoulder impingement syndrome, MRI is used mostly to evaluate for the presence of specific causes or abnormalities in the shoulder that may be the source of pain, such as a rotator cuff tear or tear of cartilage in the glenohumeral joint. In the absence of specific abnormalities, the MRI scan of a shoulder with impingement syndrome will show some generalized inflammation or collections of fluid in the area of compression. Ultrasound, like MRI, can also be used to exclude other specific abnormalities as the source of pain.

Treatment

The treatment of most athletic injuries, including shoulder impingement syndrome, can be divided into *acute* and *subacute* therapy. In the absence of long-standing pain and dysfunction or the presence of other specific shoulder abnormalities (e.g., rotator cuff tear), the treatment of shoulder impingement syndrome does not include surgery. Some potential surgical interventions are discussed below.

Acute Therapy

At the time of initial evaluation, there may be significant pain and/or dysfunction. For this, acute therapy may consist of rest, cryotherapy (ice), and nonsteroidal anti-inflammatory medications (NSAIDs) such as ibuprofen. For appropriate rest, the athlete must avoid any aggravating activity, including all overhead motion or any sport-specific activity that re-creates his or her pain. Cryotherapy can be initially used to aid in pain relief and help reduce inflammation. In addition to cryotherapy, NSAIDs are also used to reduce pain and inflammation. These medications are typically used for 10 to 14 days and only as needed thereafter.

Additional acute therapies may be used for the reduction of pain and inflammation. These may be performed by a certified physical therapist (PT or DPT) or certified athletic trainer (ATC) and may include electrical stimulation (E-stim), phonophoresis, iontophoresis, or therapeutic ultrasound. Phonophoresis and iontophoresis use sound waves and an electrical current, respectively, to push anti-inflammatory medication through the skin to the site of injury.

Subacute Therapy

Physical Therapy

After the initial pain and inflammation are addressed, physical therapy should be focused on the achievement of full and nonpainful range of motion of the affected shoulder. Once this range of motion is achieved, physical therapy is then used to restore the strength and function of the shoulder musculature. The rehabilitation program is used to restore the function of all the muscles surrounding the shoulder, including those that control the movement of the scapula.

For a nonathlete patient, the rehabilitation program is complete once the patient returns to normal activities of daily living without pain. An athlete, however, must then be guided back to sport-specific activities after full range of motion and strength are regained. Certain sport activities place a much higher demand on the shoulder joint than normal daily activities. During a return-to-sports program, the athlete is taken through exercises that simulate the demands of the athlete's sport. For example, a football quarterback is asked to re-create his throwing motion, initially with light resistance and then using lightweight dumbbells.

Other Treatments

Completion of the above treatment programs will commonly result in full recovery for most athletes. However, if a full return to his or her sport activity is not accomplished in 2 to 3 months, the following treatment options may be considered.

Steroid Injection. Sports medicine physicians often use an injection of a steroid solution into the shoulder joint or subacromial space (an area between the acromion and the head of the humerus) if chronic inflammation is thought to be the cause of shoulder impingement syndrome. The goal of the injection is to reduce the inflammation and pain to help facilitate recovery and the ability to perform the rehabilitation program. Glucocorticoid solutions are used for injection in combination with a local anesthetic, lidocaine or marcaine.

Surgery. As stated before, in the absence of long-standing problems or specific abnormalities, surgery is rarely indicated for shoulder impingement syndrome. Long-standing shoulder impingement syndrome is defined as any dysfunction that has not improved with the above therapies or has lasted longer than 3 months. If there is no improvement in the athlete's shoulder pain after 3 months of the above treatments, surgical exploration with minimally invasive arthroscopic surgery may be considered. During this procedure, the surgeon will attempt to localize the source of the athlete's pain and repair damaged tissue. Also, if a Type III acromion is noted on plain radiographs, an acromioplasty procedure may be performed. During this procedure, the surgeon removes part of the undersurface of the acromion bone to help "decompress" the area of impingement—in other words, to make more room for internal structures to avoid future compression and impingement. Following surgery for shoulder impingement syndrome, in the absence of an extensive repair for a specific abnormality, the athlete can be expected to complete a course of physical therapy in 2 to 4 weeks and begin a return to sport-specific activities in 4 to 6 weeks.

David W. Kruse

See also Musculoskeletal Tests, Shoulder; Principles of Rehabilitation and Physical Therapy; Rotator Cuff Tendinopathy; Shoulder Bursitis; Shoulder Injuries; Shoulder Injuries, Surgery for

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Shoulder Injuries

Shoulder injuries occur as a result of both acute trauma and chronic overuse and affect both bony and soft tissue structures. Acute injuries as a result of falling or collision are seen mainly in collision, contact, and extreme sports, such as hockey, football, snowboarding, and skateboarding. Overuse injuries are becoming more frequent as a result of year-round competition and sport-specific training. Overuse injuries are seen commonly in sports such as swimming, baseball, volleyball, softball, and tennis. Shoulder pain occurs in 40% to 80% of swimmers and 50% to 95% of baseball players.

Overuse injuries result from microtrauma from repetitive movements of large rotational forces. They are often associated with joint looseness, mobility impairment, or muscle imbalances. Several risk factors contribute to such injuries. These risk factors include poor mobility, muscle weakness, muscle imbalance, and shoulder blade asymmetry. Additional risk factors in children and adolescent athletes include open physeal (growth) plates, joint laxity, and underdeveloped musculature.

Injury patterns to the athlete's shoulder are sport specific. In football, the shoulder is the second most commonly injured body part, next to the knee. Shoulder injuries are most often shoulder dislocations, shoulder separations, and collarbone fractures. Bicycling results in many shoulder injuries, usually collarbone fractures and shoulder separations from falling on the shoulder. Shoulder injuries are the most common injury to the upper extremity in wrestling, with shoulder separations being the most common. Repetitive microtrauma frequently results in multidirectional instability in swimmers and gymnasts.

Anatomy

There are four bony articulations in the shoulder: (1) the glenohumeral joint, (2) the acromioclavicular (AC) joint, (3) the sternoclavicular (SC) joint, and (4) the scapulothoracic articulation. The glenohumeral joint is a ball-and-socket joint. The glenoid cavity is relatively shallow and, therefore, inherently unstable. Additional stability is provided by the glenohumeral ligaments, glenoid labrum, and capsule, as well as the rotator cuff and scapular-stabilizing muscles.

The labrum is a ring of fibrous tissue that attaches directly to the glenoid fossa. It expands the size and depth of the glenoid cavity. The superior portion of the labrum inserts directly onto the biceps tendon, and the biceps tendon inserts on the supraglenoid tubercle. The shoulder capsule has three primary bands, called the superior, middle, and inferior glenohumeral ligaments. The anterior and posterior bands of the inferior glenohumeral ligament prevent anterior and posterior translation of the humeral head. The superior margin of the anterior band of the inferior glenohumeral ligament attaches to the glenoid fossa at the two o'clock position. When the shoulder is abducted and externally rotated, this broad ligament rotates anteriorly to prevent subluxation (partial dislocation) of the humeral head.

The rotator cuff muscles are the dynamic stabilizers of the shoulder and include the supraspinatus, infraspinatus, teres minor, and subscapularis. These muscles stabilize the position of the humeral head in the glenoid fossa, rotate the humerus, and help elevate the upper extremity. They also act to depress the humeral head as a counterforce to the deltoid, which acts to elevate the arm and force the humeral head superiorly. The rotator cuff muscles rely on optimal functioning of the deltoid and scapular-stabilizing muscles. The scapular-stabilizing muscles include the trapezius, serratus anterior, rhomboids, levator scapulae, and pectoralis minor.

Normal shoulder movement requires that the scapulothoracic joint, the AC joint, and the SC joint all move together smoothly. Smooth, integrated movement of these joints is necessary to achieve full upper limb elevation. Scapular movement removes the acromion from the path of the humeral head so that it does not become impinged.

There are unique differences in structure in the pediatric shoulder compared with adult shoulders. In the skeletally immature athlete, there is a growth plate at the proximal end of the humerus where new bone is formed. Approximately 80% of the growth of the upper extremity occurs at this physeal plate. The epiphyseal plates are relatively weaker than the surrounding ligaments, predisposing children and adolescents to growth plate fractures and avulsion fractures not seen in adults. Proximal humeral closure occurs by age 14 to 16 years in girls and age 16 to 21 years in boys.

Another difference in the immature shoulder is the higher proportion of Type III collagen. As growth and development progress, Type III collagen is steadily replaced by the more stable Type I collagen seen in adults. The presence of Type III collagen in younger athletes results in more shoulder laxity, which can contribute to shoulder instability, particularly in throwing and overhead athletes.

Evaluation of Injuries

Details of Injury

Details that can diagnose shoulder injuries include the date of onset of symptoms, whether there was a specific traumatic event, the mechanism of injury, the location of pain, the presence of mechanical symptoms or instability, and management of the injury to date. Previous shoulder injuries may predispose an athlete to future injuries, particularly if the injury was not fully healed. In overhead athletes, additional information, including what sport is played, the level of competition, the number of repetitions, and where in the overhead motion pain occurs, can help determine the exact injury.

Physical Findings

Injuries to the shoulder can result in muscle atrophy, asymmetry, discoloration, or deformity, as well as winging of the shoulder blade. There may be tenderness to palpation of the bony and soft tissue structures, including the SC joint, AC joint, clavicle, acromion, scapula, greater tuberosity of the humerus, deltoid, and proximal biceps tendon.

The range of motion of the injured shoulder may be decreased or painful in forward flexion (elevation), abduction, and external and internal rotation. The range of motion of the injured shoulder may be decreased in comparison with the uninjured side. The movement of the shoulder blade may also be abnormal with a shoulder injury (dyskinesia).

Muscle strength may be decreased with a shoulder injury. Specific muscles can be tested to determine any weakness or pain. The supraspinatus strength (thumb-down abduction at 30° horizontal flexion or "empty-can" test), infraspinatus strength (external rotation with the arm adducted), external rotation with the arm in a neutral position, subscapularis strength (lift-off test performed with the hand at the lower back and pushing away from the spine against resistance), and deltoid strength (abduction with the arm at the side) against resistance may all be affected by an injury.

Biceps tendinopathy can be assessed with the Speed test and the Yergason test. The Speed test is performed with the patient standing and the shoulder forward flexed against resistance with the elbow extended and the forearm supinated. Pain or tenderness in the bicipital groove indicates a positive test. The Yergason test is performed with the elbow flexed to 90° and the forearm pronated (hand turned upward). The patient actively tries to supinate (palm of the hand turned downward) the wrist against resistance. A positive test elicits pain in the bicipital groove.

Special tests for the shoulder include the anterior apprehension relocation test, the load and shift test, the O'Brien test, the anterior slide test, the sulcus test, and impingement tests. The anterior apprehension relocation test assesses anterior instability. With the patient supine and the arm hanging off the bed, the patient's shoulder is passively moved into external rotation until guarding is appreciated (positive test) or capsular-end feel is reached. After a positive apprehension test, a posteriorly directed force is applied to relocate the humeral head in the glenoid fossa (relocation test). Apprehension disappears, and there is an increase in passive external rotation.

The load and shift test assesses for anterior as well as posterior instability. With the patient sitting, the humeral head of the affected shoulder is grasped in the examiner's hand and anterior, and posterior force is applied to determine the amount of translation within the glenoid fossa. The following grading system is helpful: Grade 0 = *no translation,* Grade 1 = *translation up to the glenoid rim,* Grade 2 = *translation onto the rim (subluxation),* and Grade 3 = *translation over the rim or dislocation.* A comparison should be made with the uninjured shoulder.

The O'Brien test can be used to assess superior labral anterior-posterior (SLAP) injuries. With the patient standing, the injured arm is flexed forward to 90° with the thumb pointed down. The examiner applies a downward force to the arm while the patient resists. Pain in the shoulder joint is considered a positive test. The thumb is then turned upward, and the maneuver is repeated. This should not be painful. Unfortunately, pain can result from this maneuver in the presence of an AC injury, biceps tendinitis, or posterior instability, resulting in a false positive. SLAP lesions can also be evaluated by the anterior slide test. The athlete stands with hands on the hips. The examiner places one hand over the athlete's shoulder, and the other hand is placed behind the elbow. The examiner then applies a force anteriorly and superiorly while the athlete pushes back against the force. A positive test results in pain localized to the anterosuperior aspect of the shoulder, a pop or click in the same area, or reproduction of the athlete's symptoms.

The sulcus sign assesses for the presence of inferior instability. The patient should be seated and completely relaxed. With the shoulder in the neutral position, the examiner exerts a downward force on the humerus, looking for the presence of a depression or sulcus at the glenohumeral joint (positive test). A positive sulcus sign may indicate generalized ligamentous laxity or multidirectional instability. If generalized ligamentous laxity is suspected, patients should be assessed for hyperextension of the elbows and metacarpal-phalangeal joints and hyperflexion of the first carpometacarpal/wrist joint.

Sometimes pain in the shoulder can result from the humeral head butting up against the acromion (impingement). Impingement tests include the Neer and Hawkins signs. They evaluate the rotator cuff and subacromial bursae. The Neer test is performed with the athlete in the seated position. The examiner places one hand on the shoulder and passively flexes the shoulder forward until pain is experienced by the athlete. The Hawkins test is also performed with the athlete seated. The examiner stabilizes the shoulder with one hand while passively internally rotating the arm with the arm forward flexed and the elbow flexed to 90°. Pain in the shoulder indicates impingement of the humeral head by the acromion. An additional impingement sign is the crossover test, which confirms AC pathology. With the patient seated, the arm of the affected shoulder is adducted across the chest. A positive test elicits pain in the AC joint.

Investigations

Investigations that may be necessary to help determine the diagnosis in shoulder injuries include X-rays, a computed tomography (CT) scan, an ultrasound scan, a bone scan, and a magnetic resonance imaging (MRI) scan. In acute injuries, X-rays including anteroposterior views with internal and external rotation as well as axillary views should be performed to look for fractures. Calcific tendinopathy, arthritis, subluxation, or dislocation, as well as impingement, may be seen on X-rays. A CT scan can provide greater bony definition.

An ultrasound scan can be used to help confirm the suspicion of a muscle or tendon tear.

Examination can be performed as a static or dynamic investigation. The size of the tear and the thickness of the intact tissue can be measured. A dynamic examination may confirm impingement.

MRI scans have become increasingly helpful with the diagnosis of rotator cuff and labral tears, although arthroscopy remains the gold standard. MRI arthrography (injection of dye into the shoulder joint) is currently the recommended diagnostic study of choice for labral tears.

Types of Injury

Various types of shoulder injuries are listed in Table 1.

Prevention of Injury

Proper technique is important to avoid injury, particularly in overhead athletes. It should be taught early and reinforced throughout an athlete's career. Year-round conditioning should be encouraged,

Table 1 Shoulder Injuries

Common	*Uncommon*	*Must Not Be Missed*
Rotator cuff strain/tendinopathy	Rotator cuff tear	Tumor
Glenohumeral dislocation	Biceps tendinitis	Referred pain from thoracic/abdominal structures
Glenohumeral instability	Fracture (scapula, humeral neck, proximal humerus in children)	Thorax outlet syndrome
Labral tears (superior labral anterior-posterior [SLAP])	Arthritis	
Clavicle fracture	Neurapraxia (burner)	
Acromioclavicular (AC) joint separation/dislocation	Sternoclavicular (SC) separation/dislocation	
Little League shoulder	"Frozen shoulder"	
Shoulder subluxation	Bursitis	
Impingement syndrome		

Source: Author.

with emphasis on core strengthening and lower extremity strengthening.

In overhead sports such as football, baseball, softball, and tennis, proper technique should be reinforced to ensure that athletes are using their lower extremity strength to help impart force to the ball and limit the stress to the shoulder. Avoid "overthrowing."

To avoid overuse injuries, appropriate rest and recovery should be ensured. Athletes should take advantage of the off-season to allow muscle recovery. Athletes should not play the same sport all year round or participate on more than one team. In children and adolescents, restrictions in the number of repetitions, such as the number of pitches and types of pitches (no sliders or curve balls), can help reduce shoulder injuries.

Return to Sports

Before an athlete with a shoulder injury returns to sports, he or she should have attained full range of motion of the shoulder and full strength of the rotator cuff and scapulothoracic muscles, as well as core and lower extremity strength. Pain should be resolved. The athlete should have progressed through a functional exercise program consisting of sport-specific activities and drills that mimic the stresses that the athlete will encounter in practice and competition. The athlete must also demonstrate the appropriate mechanics for his or her particular sport to minimize the risk of reinjury and to achieve maximal performance.

Laura Purcell

See also Acromioclavicular (AC) Joint, Separation of; Clavicle (Collarbone) Fracture; Frozen Shoulder; Glenoid Labrum Tear; Little League Shoulder; Shoulder Bursitis; Shoulder Impingement Syndrome; Shoulder Instability; Shoulder Subluxation; Superior Labrum From Anterior to Posterior (SLAP) Lesions

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Shoulder Injuries, Surgery for

The shoulder plays a major role in athletic competition. "Overhead sports" athletes are those whose primary sport involves much activity with the arm overhead. These sports include, but are not limited to, football, basketball, baseball, tennis, swimming, lacrosse, and gymnastics. These sports place particularly significant stresses and strains on the athlete's shoulder. Baseball pitchers, due to the high energy of the pitch, are a unique group of athletes who place particularly high demands on their dominant shoulder. Swimmers also rely heavily on repetitive exaggerated shoulder motions to swim fast. Shoulder injuries are more common in overhead sports athletes and occur most frequently in baseball pitchers and swimmers.

This entry reviews the anatomy of the shoulder and the types of injury that commonly occur in athletes and explains the surgeries used to repair the affected structures.

Anatomy

The shoulder is a ball-and-socket joint in which the ball is the head of the humerus and the socket is called the *glenoid*. The glenoid socket is directly attached to the scapula, or shoulder blade. Both the ball of the humerus and glenoid socket are covered in smooth cartilage that resembles the shiny white end of a chicken bone. The smooth cartilage allows the ball-and-socket bones to move against each other with minimal friction. The glenoid socket resembles a dish and is surrounded on its edges by a circular rim of rubbery cartilage called the labrum. The labrum can be thought of as an O-ring that attaches to the outer edges of the glenoid socket. The labrum serves to make the glenoid socket deeper and helps keep the ball of the humerus from moving outside the socket. The *shoulder capsule* is made up of strong elastic tissue that surrounds the head of the humerus and glenoid socket. The shoulder capsule prevents the ball of the humerus from moving outside the glenoid socket. The shoulder capsule is reinforced by *ligaments,* or areas of condensed fibrous bands, that run between the head of the humerus and glenoid socket to provide strength to the shoulder capsule.

The rotator cuff is a group of four muscles that lie on top of the shoulder capsule, surrounding the ball of the humerus and the glenoid socket. These muscles sit on top of the shoulder like the cuff of a shirt. Two rotator cuff muscles lie on top of the shoulder and are called the *supraspinatus* and the *infraspinatus*. One rotator cuff muscle sits in front of the shoulder and is called the *subscapularis*. The *teres minor* is the fourth rotator cuff muscle, and it lies in the back of the shoulder. The rotator cuff muscles all form muscle tendons that attach to the head of the humerus. The rotator cuff functions to move the shoulder in all directions. The top muscles (supraspinatus and infraspinatus) work to bring the arm above the head and are most important in overhead sports.

Surrounding the rotator cuff muscles is the *deltoid* muscle. The deltoid muscle begins at the collarbone and shoulder blade and attaches to the humerus. The deltoid muscle helps the rotator cuff move the shoulder. The *biceps* muscle lies in the front of the arm and helps bend the elbow. The biceps muscle in the arm becomes a cordlike *biceps tendon* near the shoulder. In the shoulder, the biceps tendon attaches to the glenoid socket at the top of the labrum. There are also multiple *bursa* around the shoulder. A bursa is a small fluid-filled sac that occurs around tendons and allows the tendons to move without generating friction with nearby bones. The most prominent bursa in the shoulder lies below the deltoid muscle and above the rotator cuff tendons.

Shoulder Joint Function

The ball-and-socket nature of the shoulder allows the shoulder to move more than any other joint in the body. The labrum, capsule, and ligaments of the shoulder must strike a delicate balance between allowing the shoulder to move in all directions and preventing the ball of the humerus from moving out of the glenoid socket. The strength and power of the shoulder come from the rotator cuff muscles and the deltoid muscle. Athletes must develop their shoulders' strength and mobility to accommodate the demands of their sports. Baseball pitchers normally have significantly more strength and different motion ranges in their throwing shoulder as compared with their other shoulder. The best swimmers tend to have loose shoulder joints on both sides, which allows for great shoulder motion. Shoulder injuries can occur when the stress and strain of the sport or activity prevail over the ability of the shoulder to perform its function.

Shoulder Joint Injuries

Most athletic shoulder injuries are muscle strains, tendinitis, or bursitis. Muscle strains represent microscopic muscle tears that occur when the muscle is stretched more than it can withstand. Muscle strains can occur in the rotator cuff, biceps, and deltoid muscles. These injuries are treated with rest and heal on their own over time. Tendinitis occurs when the muscle tendon (the part of the muscle that attaches to the bone) becomes irritated or inflamed. Tendinitis occurs most commonly in the rotator cuff muscle tendons near where they attach to the head of the humerus. Rotator cuff tendinitis is often seen in repetitive overhead sports such as tennis, swimming, and baseball. Many times, a small injury to the rotator cuff tendon is ignored by the athlete, who continues to stress and strain the tendon through playing the sport. Over time, the body responds by sending blood cells to the rotator cuff tendon in an attempt to repair the injury. An inflammatory response is generated by the blood cells, which causes pain and swelling in the area of the rotator cuff tendon. Rotator cuff tendinitis is treated with rest, ice, anti-inflammatory medications (e.g., ibuprofen), and physical therapy focusing on shoulder muscle strengthening. Bursitis is a similar inflammation of a shoulder bursa. This can occur when the nearby tendon is inflamed, as is often the case in rotator cuff tendinitis. Shoulder bursitis is treated like rotator cuff tendinitis. In addition, the physician may elect to inject a corticosteroid (an injectable anti-inflammatory medication) into the shoulder bursa to help decrease inflammation in that area.

The most common shoulder injuries in sports that may require surgery are rotator cuff tendon tears, labrum tears, and shoulder dislocations. Rotator cuff tendon tears occur when the rotator cuff tendon pulls away from its attachment to the humerus. This can occur when a sudden force is placed on the arm, pulling the arm away from the body. Rotator cuff tendon tears can also occur in the setting of rotator cuff tendinitis if the athlete continues to stress the inflamed tendon. Rotator cuff tendon tears most commonly occur in overhead throwing athletes in the supraspinatus tendon at the top of the shoulder. Rotator cuff tears can be diagnosed by a physical exam as the athlete will have weakness with overhead shoulder motion. When a physician suspects a rotator cuff tear, an MRI scan of the shoulder is usually obtained and can be used to diagnose a rotator cuff tear. Rotator cuff tendon tears can be of partial thickness (where only a part of the thickness of the tendon has pulled off its attachment on the humerus) or full thickness (where the entire thickness of a portion of the tendon has pulled off the humerus). Many partial-thickness rotator cuff tendon tears will heal on their own and can be treated without surgery. Full-thickness tendon tears often require surgical repair.

Labral tears are most common in overhead throwing athletes such as baseball pitchers. These injuries usually cause deep pain and popping of the shoulder joint with overhead activities. Labral tears occur in many different forms and sizes. When the labrum tears at the top of the glenoid socket, it is called a SLAP tear (which in medical terms stands for superior labrum anterior-posterior). These labral tears are important because the biceps tendon attaches to the labrum in this region. When the physician suspects a labral tear, an MRI scan is often obtained to evaluate the shoulder labrum. Sometimes dye is injected into the shoulder prior to the MRI scan to help the radiologist identify the labrum and determine if there is a tear. Many labral tears do not require surgery. Surgery is usually reserved for overhead throwing athletes who have deep shoulder pain and popping that does not improve after a period of rest and rehabilitation.

Shoulder dislocations occur when the ball of the humerus slips outside the glenoid socket. Because of its inherent mobility, the shoulder is the joint that is most likely to dislocate in the body. Shoulder dislocations most commonly occur when the ball of the humerus moves outside the glenoid socket and toward the front of the shoulder (an anterior shoulder dislocation). This occurs when the arm is extended and a force pushes the arm backward while levering the head of the humerus forward. When the shoulder dislocates, the head of the humerus must be “reduced” or put back in the glenoid socket. This can sometimes be done on the playing field by the athletic trainer. At other times, shoulder muscle spasms prevent the shoulder from being reduced easily. In these cases, the athlete is usually taken to the emergency room, where medication is used to relax the muscles while a physician manipulates the shoulder back into place.

When the humeral head dislocates out of the glenoid socket toward the front, the shoulder capsule and ligaments, and occasionally the front of the labrum, are usually torn. An MRI scan may be obtained to determine exactly what structures have been injured by the dislocation. Many shoulder dislocations are treated without surgery. The athlete is usually placed in a sling for a period of time before undergoing a course of physical therapy to restrengthen the shoulder. When a shoulder dislocation occurs in a young athlete who participates in overhead contact sports, the chance of the shoulder dislocating again is very high. Also, in patients who have had shoulder dislocations in the past, the chance of having another dislocation is very high. In these and other cases of shoulder instability, surgery may be recommended to repair the torn labrum and to retighten the front of the shoulder capsule and ligaments to prevent future shoulder dislocations.

Surgery: Rotator Cuff Repair

Surgery for a full-thickness rotator cuff tear involves repairing the torn rotator cuff tendon back to where it attached on the humeral head. This surgery can be done through a large incision (open technique) or through multiple tiny incisions with the aid of an arthroscope (arthroscopic technique). The choice of technique depends on the pattern of the tear and the preference of the surgeon. Open techniques require that part of the deltoid muscle be detached and then repaired to allow access to the torn rotator cuff tendon. Recently, arthroscopic equipment and skills have improved considerably, allowing many tears to be repaired using this technique. Arthroscopic rotator cuff repair often results in less pain immediately after surgery, although the overall recovery time and time to tendon healing are not changed.

During rotator cuff repair, in most cases, one or more tiny metal or absorbable anchors are inserted into the bone of the humeral head where the torn rotator cuff is supposed to attach. The anchors are connected to strong suture material that is used to tie the torn rotator cuff back to where it attached on the humeral head. The number of anchors used depends on the size of the tear. After surgery, patients are placed into a sling that is typically worn for approximately the first 3 weeks after surgery. For the first 6 weeks after surgery, no active lifting of the arm over the head is allowed. Full recovery from rotator cuff repair back to sporting activities often takes 4 months or much longer for overhead throwing athletes.

Surgery: Labral Repair

When surgery is necessary for labral tears in the shoulder, an arthroscopic technique is most commonly employed. In these cases, multiple small incisions (termed arthroscopic *portals*) are made around the shoulder. The arthroscope (a small, thin camera) is placed through one of these portals and into the shoulder joint (between the humeral head and glenoid socket). With the arthroscope in the shoulder, the surgeon is able to look at a monitor and identify the labrum (the rubbery O-ring around the glenoid socket) to determine if there is a tear. The surgeon decides how to proceed based on the size, shape, and location of the labral tear.

For smaller tears or tears that are frayed and degenerated, the surgeon may elect to remove only the torn portion of the labrum and leave the rest of the labrum alone. This is done with the aid of a miniature motorized shaver that is placed through an arthroscopic portal. For larger tears or tears that involve the labrum on the top of the shoulder (where the biceps tendon attaches), the surgeon may elect to repair the torn portion of the labrum back to where it belongs on the glenoid socket. This is done by placing tiny metal or absorbable anchors through an arthroscopic portal and into the glenoid socket at the location of the tear. Strong suture material is attached to the anchor, and this suture is then passed around the torn labrum and used to tie the torn labrum back down to the glenoid socket. After labral repair surgery, most patients are kept in a sling for approximately 3 weeks before starting a course of physical therapy. Return to sports takes approximately 3 to 4 months as the repair site has to heal. For baseball pitchers and overhead throwing athletes, return to full throwing can take as long as 9 to 12 months.

Surgery: Shoulder Instability

Surgery for shoulder instability involves repairing the structures that were injured when the head of the humerus dislocated out of the glenoid socket. These injured structures usually include a combination of the shoulder capsule, ligaments, and front part of the labrum. Repair of these structures can be done through one large incision on the front of the shoulder (open technique) or through multiple small incisions around the shoulder (arthroscopic technique). In the past, the open technique has produced the best results, but recent advancements in arthroscopic equipment and skill have made arthroscopic surgery an equal or better alternative in many cases.

The goal of surgery for shoulder instability is to repair the torn structures caused by the dislocation and to tighten the shoulder capsule just enough to prevent the humerus from dislocating again. If the shoulder capsule is overtightened by surgery, some shoulder motion will be lost, and the athlete will have trouble returning to high-level sports. If the shoulder capsule is not tightened enough, the humeral head may dislocate again. Regardless of whether an open or an arthroscopic technique is used, the front part of the labrum is first examined. A tear in the front part of the labrum is often seen and is termed a *Bankart tear* (named after the physician who discovered it). This part of the labrum has the shoulder capsule ligaments attached to it and must be repaired back to the glenoid socket. Repair is usually done by placing tiny metal or bioabsorbable anchors in the front part of the glenoid socket. Strong suture material attached to the anchors is then used to tie the front part of the labrum back to the front part of the glenoid socket (a *Bankart repair*). This helps restore the bumper effect of the front part of the labrum on the glenoid socket, which helps keep the humeral head from coming out of the front of the shoulder. In addition, Bankart labral repair tightens the front shoulder capsule ligaments that are attached to this part of the labrum. If further tightening of the shoulder is necessary, sutures are then placed in the front part of the shoulder capsule to retighten it.

After surgery for shoulder instability, most patients are placed in a sling for 3 to 4 weeks. The arm is kept near the body, and active motion of the arm away from the body is not allowed for the first 6 weeks after surgery. Approximately 3 months of physical therapy is necessary after surgery to restore shoulder motion and strength. Return to sports generally occurs at about 4 to 6 months after surgery.

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See also Acromioclavicular (AC) Joint, Separation of; Clavicle (Collarbone) Fracture; Frozen Shoulder; Glenoid Labrum Tear; Shoulder Injuries; Shoulder Instability; Superior Labrum From Anterior to Posterior (SLAP) Lesions

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Shoulder Instability

Glenohumeral instability is a common shoulder disorder, particularly among young athletes. Traditionally, shoulder instability has been divided into two types: those that were initially caused by a traumatic event and those associated with generalized ligamentous laxity.

Peak incidences of traumatic shoulder dislocation occur in a bimodal distribution. Men are at the highest risk of dislocation between 20 and 30 years of age, whereas women more frequently experience dislocation of the shoulder between 61 and 80 years of age. Risk factors for shoulder dislocation include falling on an outstretched arm; a direct blow to the shoulder, as in an automobile accident; force applied to an outstretched arm, as in a football tackle; and forceful throwing, lifting, or hitting. Sports that place an athlete at a higher risk of shoulder dislocation include football, wrestling, and hockey.

Generalized ligamentous laxity can also place an athlete at a higher risk of dislocation. Although ligamentous laxity can be congenital, activities such as swimming, gymnastics, and weight lifting, which frequently subject the shoulder to extremes of glenohumeral motion, can stretch out the capsule and place the shoulder at a higher risk of dislocation.

Anatomy

The glenohumeral joint is made up of a ball-like humeral head rotating on a shallow, dishlike surface, the glenoid. The bony anatomy of the glenohumeral joint allows the shoulder the widest range of motion of any joint in the body. Because of this wide range of motion, the shoulder is very dependent on soft tissue restraints to prevent dislocation.

The soft tissue restraints of the shoulder include the glenoid labrum, the surrounding capsule and ligamentous structures, and the rotator cuff musculature.

The glenoid labrum is a border of soft tissue that surrounds the bone of the glenoid and effectively deepens the glenohumeral articulation. The glenoid labrum may provide stability against humeral head translation.

The capsule extends from the periphery of the glenoid around the humeral head to the periphery of the articular cartilage. The capsule is thickened in three distinct areas. These thickenings make up the glenohumeral ligaments. The ligaments function to stabilize the shoulder by becoming taut in different positions of shoulder motion.

The superior glenohumeral ligament and middle glenohumeral ligament stabilize the shoulder against inferior subluxation or dislocation when the arm is at the patient's side. They also assist in resisting posterior translation. The primary function of the middle glenohumeral ligament is to limit external rotation with the arm at 45° of abduction. The inferior glenohumeral ligament forms a sling with an intervening axillary pouch that tightens anteriorly as the shoulder extends, preventing anterior dislocation, and tightens posteriorly as the shoulder flexes, preventing posterior dislocation.

The surrounding rotator cuff musculature provides dynamic shoulder stabilization. Weakening of the rotator cuff musculature can contribute to shoulder instability.

In 1923, Bankart described a lesion that occurs during a shoulder dislocation and ultimately leads to shoulder instability. The lesion is a detachment of the anterior-inferior portion of the labrum from the rim of the glenoid. The lesion occurs as the labrum is sheared from the glenoid rim during a shoulder dislocation.

In multidirectional instability, the capsule is often enlarged and may be weakened from multiple episodes of subluxation or dislocation.

Causes

It is important to understand the difference between laxity and instability. Laxity refers to the extent to which the humeral head can be translated on the glenoid. Instability is an abnormal increase in glenohumeral motion that causes symptoms such as pain, subluxation, and dislocation and functional symptoms such as catching or locking.

Individuals who have congenitally lax joints are at an increased risk for shoulder instability. Laxity can also be acquired through activities that involve extremes of glenohumeral motion that may stretch out the shoulder capsule, such as swimming, gymnastics, and weight lifting.

The most common direction of traumatic dislocation is anterior. Traumatic anterior dislocation commonly occurs with the arm in a position of abduction/external rotation. Activities that place the shoulder at risk for dislocation and subsequent instability include contact sports, falls on an outstretched arm, direct blows to the shoulder, and forceful throwing, lifting, or hitting. Traumatic dislocations that occur in patients less than 20 years old are at a significant risk for redislocation. A youth or adolescent with a first-time dislocation is at a 70% to 100% risk of dislocating again.

Posterior dislocation occurs when an axial load is placed on a flexed, adducted, internally rotated shoulder. Posterior instability can occur as a result of repetitive episodes of loading the posterior capsule, as is common with an offensive lineman. Other causes of posterior instability include seizures and motor vehicle accidents.

Inferior instability is most commonly associated with multidirectional instability.

Symptoms

An athlete who presents after a traumatic dislocation will often complain of pain that is usually worse with activity or with the arm in certain positions.

The pain is often associated with the direction of the dislocation (i.e., posterior shoulder pain with posterior dislocations). Symptoms may be aggravated by overhead activities, carrying objects at the side, or overuse. Other complaints may include weakness, a sensation of the shoulder slipping out of place, or numbness and tingling of the affected extremity. Nocturnal pain is variable.

As instability worsens, symptoms begin to occur in midranges of glenohumeral motion common to activities of daily living.

Diagnosis

Physical Examination

The physical examination of shoulder instability should begin with an inspection of the shoulder and its surrounding musculature. Findings that may be common with glenohumeral instability include atrophy of the biceps, supraspinatus, or infraspinatus.

The range of motion of the involved shoulder should then be compared with the opposite shoulder. Restrictions to motion as well as hypermobility should be noted.

Special tests for the shoulder include the sulcus sign, the drawer test, the anterior and posterior apprehension test, the relocation and release tests, the load and shift test, and the jerk test.

The drawer test is useful for evaluating increased anterior and posterior shoulder laxity. The examiner performs this test by stabilizing the scapula and clavicle with one hand while gently pushing the humeral head as far forward and then as far back as possible with the other hand. Normal humeral head translation is approximately 50% of its anterior-to-posterior dimension.

Inferior laxity is demonstrated by the sulcus sign. This test is performed with the examiner standing at the patient's side. The patient is encouraged to relax as the examiner grasps the patient's arm just above the elbow and gently pulls distally while observing the lateral acromion. As the humeral head translates inferiorly, a sulcus is formed between the acromion and the humeral head. The size of the sulcus should be compared with the opposite shoulder.

The anterior apprehension test is the classic provocative test for anterior instability. It is performed by placing the arm in 90° abduction, extension, and external rotation with the elbow flexed to 90°. The examiner then progressively externally rotates the shoulder. A patient with anterior instability will complain of pain in the anterior shoulder or apprehension of impending dislocation.

The relocation test increases the specificity of the anterior apprehension test for cases of subtle instability. It is performed by placing the shoulder in a position of apprehension and then applying a posteriorly directed force over the humeral head. A patient with instability will feel decreased pain and reduced apprehension. When the examiner removes the posterior force, the pain and apprehension return (release test).

Anterior and posterior instability can also be tested with the load and shift test. This test is performed with the patient lying on the examination table. The table serves to stabilize the scapula. The patient's arm is slightly abducted from his or her side. The examiner then stabilizes the scapula with one hand and grasps the proximal humeral shaft with the other hand. While slightly compressing the humeral head against the glenoid, the examiner attempts to slide the proximal humerus off the anterior and then the posterior glenoid rim. In the stable shoulder, anterior or posterior translation of approximately half the distance of the humeral head will occur.

The jerk test is an additional test for posterior shoulder instability. It is performed by placing the patient's arm in 90° flexion, adduction, and internal rotation with the elbow flexed to 90°. The examiner applies a posteriorly directed force at the elbow, attempting to push the humeral head posteriorly off the glenoid. A jerk or clunk is felt as the humerus slips over the edge of the posterior glenoid rim.

Imaging

Imaging of the unstable shoulder should include the three standard views: anterior-posterior (AP), scapular Y, and axillary. Although the dislocated shoulder frequently only involves soft tissue injury, as many as 55% of traumatic dislocations have an associated bony injury.

Additional views that may be helpful in visualizing bony injury include the *West Point view* and the Stryker notch view. The West Point view is taken with the patient prone, with the arm abducted to 90° and hanging over the side of the table. The radiograph is taken with the X-ray beam aimed anteriorly and 25° medially. It is most helpful in detecting anterior-inferior glenoid rim fractures (bony Bankart lesions).

The Stryker notch view brings Hill-Sachs lesions (humeral head impaction lesions) into view. The radiograph is taken in an anterior-to-posterior direction, aiming the beam 10° cephalad with the patient supine with his or her hand on top of his or her head with the elbow flexed.

Because instability most commonly involves a soft tissue component, magnetic resonance imaging (MRI) is usually performed for diagnosis and surgical planning. To improve visualization of soft tissue avulsions (labral tears), a dye can be injected into the glenohumeral joint prior to the MRI scan (an MR arthrogram). Recent literature states that the sensitivity of an MRI scan alone in diagnosing a labral tear is 91% to 93%. The addition of dye in the glenohumeral joint (MR arthrogram) improves the sensitivity to 96%.

Treatment

Nonsurgical

Treatment of instability is primarily nonsurgical. Rehabilitation usually begins with a period of activity modification and rest. A short period of immobilization may be required for pain control in a patient with multidirectional instability. After a traumatic dislocation, younger patients (less than 30 years old) should be immobilized in a sling for 3 weeks to allow the tissues to heal prior to exercises to restore strength and motion. Older patients are at greater risk for shoulder stiffness but with a reduced risk of developing recurrent instability. Some physicians therefore have patients begin exercises to restore range of motion after only 1 week of immobilization.

Modalities to help reduce pain such as ice, anti-inflammatory medications, and electrical stimulation can also be of great use. Overhead activities are initially avoided. Once the patient's pain is well controlled, an exercise program is instituted to help restore normal, painfree range of motion. Exercises should include strengthening of the deltoid, periscapular, and surrounding rotator cuff musculature.

Surgical

Arthroscopy

Arthroscopy can be used as an effective tool for both diagnosing and treating shoulder instability. Some of the benefits of shoulder arthroscopy include avoiding the morbidity associated with a large incision and releasing the subscapularis muscle from its attachment site on the proximal humerus required in an open surgical approach.

Arthroscopy is additionally beneficial because it allows the physician to visualize the relationship of the humeral head to the glenoid and the integrity of the ligaments and capsule as the shoulder is taken through a range of motion. The labrum can be inspected and probed for any areas of detachment. The shoulder capsule, which is often enlarged and weakened from multiple dislocations, can also be evaluated.

Shoulder instability is treated by tightening the loose shoulder capsule. This is done by placing plicating stitches in the capsule and typing them through special arthroscopic cannulas. The labrum, if torn from its attachment on the glenoid, can be repaired by placing small anchors along the edge of the glenoid. The anchors have a suture attached to them that allows the surgeon to secure the torn labrum back to the bone while it heals.

Open Treatment of Shoulder Instability

Several methods have been developed to treat shoulder instability through an open (nonarthroscopic) procedure. Some of these involve repairing the capsule in a shortened fashion, while others are meant to limit the patient's external rotation to prevent her or him from getting into a position of potential dislocation.

An open procedure is performed by making a longitudinal incision in the axillary crease. Dissection is carried down through the subcutaneous tissues to an interval between the pectoralis major and the deltoid muscles. The subscapularis muscle is then identified and released from its attachment on the proximal humerus. The capsule is then split. Labral tears, if present, are identified and repaired. The capsule can then be tightened on closure.

After Surgery

As a general rule, the shoulder is protected in a sling for 4 to 6 weeks after surgical repair. The sling should be removed several times each day for elbow and wrist range-of-motion exercises.

During the first 2 weeks after surgery, the patient is allowed to perform pendulum-type exercises with the arm hanging at his or her side while he or she gently swings the arm in small circles.

Formal physical therapy begins after the 2-week postoperative visit. Initially, the patient is allowed to forward-flex his or her shoulder to 90°. External rotation is limited to neutral for the first 6 weeks. At 6 weeks, the patient is allowed to increase the external rotation to 30°. Full external rotation range of motion is allowed at 4 months postoperatively. Progressive strengthening exercises are begun at 6 weeks postoperatively. Return to sports is allowed at 4 months postoperatively once 90% of the strength and a functional range of motion have been regained.

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See also Acromioclavicular (AC) Joint, Separation of; Clavicle (Collarbone) Fracture; Frozen Shoulder; Glenoid Labrum Tear; Shoulder Injuries; Shoulder Instability; Superior Labrum from Anterior to Posterior (SLAP) Lesions

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Shoulder Subluxation

The shoulder joint is more complex than other joints because it has a full 360° of motion. This is made possible by the structures making up the joint itself. The joint is made up of the placement of the ball of the humerus on the glenoid portion of the scapula. This can be likened to a "bowling ball sitting on a golf tee," where the top portion of the humerus, or head, is the bowling ball and the smaller glenoid is the tee. Just as the ball is held in place by the rim of the tee, the humerus is held in place by sitting on the glenoid and is supported by a rim of cartilage called the labrum, just as a golf tee has a rim. Because this does not allow much stability, there are numerous soft tissue structures to hold this joint together. Ligaments, with the most important being the inferior glenohumeral ligament, hold the humeral head on the glenoid. A soft tissue capsule holds the structure together. Muscles called the supraspinatus (needed for forward flexion), infraspinatus and teres minor (needed for external rotation), and subscapularis (needed for internal rotation) move the humerus and, thus, allow the humerus to move on the glenoid. In most patients, this is a stable arrangement; however, in some, there can be instability or too much perceived movement. Such instability can be intrinsic to an individual. When the instability produces symptoms, then it becomes pathologic and problematic to the patient. When this instability allows the shoulder to ride up on the labrum, producing feelings in the patient as if the shoulder is going to "pop out" or dislocate, which it does not do, the action of the shoulder is referred to as having undergone a subluxation.

Symptoms

Shoulder subluxation is perceived by the patient as a shoulder that is "moving too much," "moving in ways it should not," or "making noise" during activity. Patients often report that the shoulder *feels* as though it were "popping out" but is not actively dislocating. This is especially evident in shoulder-dependent sports such as swimming or throwing sports. In addition to these "unstable" feelings, patients can also feel pain deep in the glenohumeral joint or sometimes numbness going down the same-sided arm. This can be due to the movement of the humerus on the glenoid and by associated contact of nerves close to the joint by the moving humerus. Often, the subluxation will worsen with each successive motion that places the shoulder in the dependent position. This position has the affected arm in 90° flexion and 90° abduction and external rotation. The shoulder does not necessarily have to be in this position for subluxation to be perceived, but it is the more common position in which to feel the shoulder begin to subluxate. Increasing symptomatology, associated numbness, and a feeling as though the shoulder is going to dislocate often bring patients to the physician's office.

Types of Perceived Instability

It is the physician's job to recognize in which way the patient perceives subluxation and what the underlying cause of the movement is. The most common way that patients feel the shoulder moving is with increasing motion forward, or anterior subluxation. Backward, or posterior, motion is relatively rare. Some patients can feel movement more out of the bottom of the shoulder joint, or inferior. Still others can have multidirectional movement, in which they feel the shoulder move in a combination of all these motions. The reasons for a subluxating shoulder can include a genetic predisposition to abnormally loose cartilage that makes up the supporting soft tissue structures, injury to the joint or its surrounding structures, or a combination of both. Sports with a high demand on the shoulder, such as throwing sports, often make subluxating shoulders worse.

History and Physical Examination

The history is often the most important factor in the diagnosis of shoulder subluxation. This aids the physician in determining in which direction the shoulder is moving to produce the feelings of subluxation. Physical examination is also extremely important. Range of motion and strength are assessed to determine if there is a neuromuscular reason for the subluxation. Certain structures, such as a tear in the rim of the glenoid labrum, are tested physically to see if injury to these structures is the cause of the instability. Finally, the physician manipulates the shoulder in various planes in an effort to reproduce the feeling of subluxation within the patient or actively move the shoulder in a position that can make the patient feel as if the shoulder is about to "come out of joint." Often the physician checks one position at a time for movement or complaints of subluxation.

Diagnostic Testing

Diagnostic testing for shoulder subluxation is often directed at the shoulder structures to determine if they are the cause of the abnormal movement. X-rays can determine if there is damage to the bony structures of the shoulder, leading to subluxation. Computed tomography (CT) is also a good test to examine bone. Magnetic resonance imaging (MRI) with the addition of contrast material, called an *MR arthrogram*, can allow the physician to visualize any damage to soft tissue structures as a possible reason for subluxation.

Treatment

Nonsurgical

Treatment for shoulder subluxation is directed toward stabilizing the shoulder and preventing excess movement. The first and least invasive course of treatment is to perform physical therapy to attempt to have the muscles of the shoulder stabilize the humerus and glenoid tighter within the joint. Assistive braces or harnesses can be used for stabilization of the shoulder by preventing movements that would lend the shoulder to dislocation. These can only be used in sports or positions in certain sports that would not require the arm to be in full forward flexion, full abduction, or full external rotation. Return to play can follow physical therapy, provided that the patient has diminished symptoms, full active range of motion of the shoulder, and full strength within the shoulder.

Surgical

If stability cannot be maintained with physical therapy, surgery is often considered. With surgery, if there is a damaged structure, the physician will attempt to repair the damaged structure. With cases of nontraumatic origin, such as genetically "loose" soft tissue, surgery will be attempted to make the shoulder joint soft tissue tighter to hold the humerus on the glenoid to prevent subluxation. Surgery is usually successful. Return to play after surgery for recurrent subluxation is often possible 4 to 6 months after the procedure and associated physical therapy. There is often the risk of recurrent symptoms within the shoulder if the patient returns to sports, especially one that is very shoulder dependent. This is often seen in swimmers. Athletes who were stable postsurgery often again become unstable because of the high demands placed on the shoulder joint by their sport.

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See also Acromioclavicular (AC) Joint, Separation of; Shoulder Dislocation; Shoulder Instability

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Sickle Cell Disease

Sickle cell disease (SCD) is caused by a mutation in hemoglobin, the oxygen-carrying component of red blood cells (RBCs). This change in hemoglobin causes RBCs to become abnormal. Normally flexible and oval-shaped, RBCs in SCD lose their flexibility and assume a rigid, "sickle" shape. This change in shape hinders the ability of RBCs to travel through vessels. Since the role of RBCs is to carry oxygen throughout the body, sickling prevents oxygen from getting to vital areas, leading to a number of major complications.

Those who receive two sickle cell genes from their parents present with SCD, while those who receive one sickle cell gene and one normal hemoglobin gene are referred to as sickle cell trait (SCT) carriers. Although carriers possess one sickle gene, they often do not present with the major complications seen in those with two genes due to the one normal hemoglobin gene. Both SCD and SCT protect individuals from malaria, making the sickle cell gene predominant in people (or their descendants) in places where malaria is widespread, such as sub-Saharan Africa. An estimated 8% of African Americans are SCT carriers, and other populations with the sickle gene include the Mediterranean, Middle Eastern, Caribbean, Indian, and South and Central American populations.

Impact on Athletes

The majority of people with SCD do not participate in strenuous physical activity due to the increased risk of sickling caused by lower oxygen levels and anemia resulting from RBC destructions. Although most people with the SCT do not experience any symptoms, intense physical activity can produce exertional sickling. The causes of this exertional sickling are low levels of oxygen, metabolic acidosis, overheated muscles, and RBC dehydration. It is most likely to begin after 2 to 3 minutes of any all-out exertion, and as with SCT, the sickling leads to blockage of the blood vessels and eventual muscle breakdown due to the lack of blood supply. This muscle breakdown can threaten the lives of athletes.

Exertional sickling is extremely dangerous to athletes and ranks as the number four cause of nontraumatic sports deaths in high school and college athletes. In the past 40 years alone, exertional sickling has killed at least 15 football players and accounted for 5% of sudden, nontraumatic sports deaths in high school and college athletes in the past decade. When comparing SCT with normal controls, the relative risk of exercise-related death was 30 times greater with SCT. The data show that the more strenuous the activity is, the greater the sickling.

Signs and Symptoms

Sickling collapse due to exertional sickling is often confused with cardiac or heat collapse. However, there are subtle differences. Athletes with sickling collapse do not lose consciousness, and they often experience cramping, not seen with cardiac collapse. Unlike heat collapse, the core temperature in those with exertional sickling is not greatly elevated.

Other signs and symptoms include the following:

- Cramping with no prior muscle twinges
- Pain
- Inability to catch one's breath
- Fatigue
- Generalized muscle weakness

If treated appropriately, sickling players recover quickly.

Safety

Sickling collapse due to exertional sickling is a medical emergency. The athletes should immediately have their vital signs checked and should be administered oxygen. The administration of oxygen often can prevent further worsening of symptoms as the sickling cells will return to their normal shape. If the athlete's condition does not improve, he or she should immediately be brought to the hospital.

Although SCT athletes are at increased risk of sudden death, this should not prevent them from participating in sports. If simple precautions are taken, the risk of exertional sickling greatly decreases. The following are some of these precautions:

- Gradual progressions in training with longer periods of rest
- Stopping participation in the activity if any of the above symptoms present themselves
- Emphasizing hydration
- Avoiding heat stress
- Having supplemental oxygen available
- Educating athletes on the signs and symptoms

Screening

All newborns in the United States are screened for the sickle cell gene. Athletes who are carriers of the trait should inform their coaches as well as trainers of their condition to ensure a safe environment. Screening is inexpensive and reliable. In the absence of screening or if an athlete is unsure of his or her status, screening should be completed prior to any strenuous exercise regimen.

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See also Epstein-Barr Virus, Infectious Mononucleosis, and Splenomegaly; Infectious Diseases in Sports Medicine; Presports Physical Examination

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Side Stitch

Side stitches are associated with vigorous physical activities such as walking fast, running, swimming, cycling, and aerobic exercise. The longer medical term—*exercise-related transient abdominal pain*—is both a definition and a description of the symptoms: a painful but temporary condition associated with exercise that affects the lower (right) side of the abdominal wall.

A study conducted by Morton and colleagues (2005) in Australia, and published in the *Journal of Science and Medicine in Sport,* showed that among 848 distance runners, 27% experienced side stitches and 46% felt pain on the right side. Side stitches seem to affect exercisers below the age of 20 more than they do older adults, women more often than men, and those who are not in good physical condition more than well-conditioned individuals. Relatively few major studies have investigated the topic, and while information coming from those studies is relevant, it cannot be considered conclusive.

Causes

Side stitches among runners may be the result of the pumping action of legs putting pressure on the diaphragm from below, with the rapid breathing associated with strenuous physical activity expanding the lungs and placing pressure on the diaphragm from above at the same time. The combined effect is one of pinching the diaphragm, reducing the flow of blood and oxygen, and causing noticeable pain in the side. While this scenario seems plausible, it is a theory that has not been proven by scientific research and one that does not seem to account for side stitches in exercisers who do not walk or run.

When a fitness walker or distance runner pounds his or her legs against the ground while taking rapid breaths, the connective tissue that extends from the diaphragm to the liver can be stretched. That stretched, stressed tissue could also be responsible for causing pain in the side.

The amount and type of food consumed before an exercise session may place an additional stress on the diaphragm, again potentially causing side stitches. Whether the food-exercise association is real, there are ways to minimize the negative effects of foods and beverages on exercise without compromising athletic performance. These strategies are discussed below, in the Prevention section.

Although not warming up adequately before exercise has been mentioned as a possible cause of side stitches, there is no evidence to support that claim. In fact, the Australian study found that the incidence of side pain occurred equally during the first, middle, and latter segments of the 14-kilometer race. If the side stitches had occurred only during the initial part of the race, an inadequate warm-up might have been the cause. That was not the case.

In spite of some logical explanations and a few well-designed studies, the exact cause of side stitches remains an exercise science mystery. Nevertheless, scientists, sports medicine physicians, elite athletes, and weekend exercisers agree that the pain is as real as it is temporary and that the discomfort can be minimized, if not eliminated.

Symptoms

Side stitches have two distinguishing symptoms. The first is a stabbing pain on the lower right side of the abdomen, and the second is pain that subsides almost immediately after the cessation of exercise. Side pain that persists regardless of exercise patterns is not exercise-related transient abdominal pain, and people who have that symptom should seek medical attention.

Treatment

The immediate treatment for side stitches is simply to stop doing whatever causes the pain, wait a couple of minutes, and resume the activity. Some people try to temporarily decrease the pain by stopping, bending forward, and tightening the abdominal muscles. There is no long-term treatment, but there are ways to lessen the probability that the condition will develop in the first place.

Prevention

The measures a person takes to avoid side stitches may be effective for that individual but not necessarily for all exercisers. Ten suggestions for preventing side stitches follow:

1. To focus on breathing patterns that might be associated with side stitches, exhale through pursed lips.
2. Before exercising, stretch by extending the left arm upward and leaning toward the right. Hold for 20 to 30 seconds, and repeat the stretch with the right arm up while leaning to the left.
3. Practice breathing deeply during exercise to stretch the diaphragm.
4. Change patterns of breathing while running or walking. For example, inhale, hold for one second, exhale. Then inhale, hold for 2 seconds, exhale. Next, inhale, hold for 3 seconds, exhale.
5. Change the pace of walking or running during an exercise session.
6. To address potential nutrition-exercise interaction, eat moderately sized, low-fat meals 2 to 3 hours before a training session or event.

7. Experiment with various sources of calories to discover the ones your body can tolerate without developing side stitches. Examples include energy gels, sports drinks, fruits, and grains.
8. Do not test a new or different kind of food or beverage the day of an important event.
9. Eat a familiar, easily digested, low-fat or no-fat snack an hour before a workout. Half a sandwich, a sports drink, fig bars, and granola bars are possible choices.
10. Drink 10 to 16 ounces (oz; 1 oz = 29.57 milliliters) (two cups) of cold fluid approximately 15 to 30 minutes before practice sessions or athletic events, and drink 4 to 8 oz of cold fluid every 10 to 15 minutes during exercise.

Jim Brown

See also Abdominal Injuries; Dietitian/Sports Nutritionist; Nutrition and Hydration

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Sinusitis in Athletes

Sinusitis (or rhinosinusitis) is the inflammation of the sinus airspaces and epithelial lining within the bones of the face. The symptoms associated with it are responsible for a significant percentage of athletes' visits to training rooms and physicians throughout the year. It can be difficult to differentiate between sinus infections and other upper respiratory infections because the symptoms overlap. Understanding the difference, however, can help an athlete return to play and perform at a normal level more quickly.

Anatomy

The sinuses are air pockets within the skull that include the maxillary sinuses, located within the cheek bones; the ethmoid sinuses, located behind the bridge of the nose; the frontal sinuses, located above the eyes in the center of the eyebrows; and the sphenoid sinus, located behind the ethmoid sinuses and behind the eyes. When the mucus-clearing cilia of the epithelial tissue that lines the sinuses cannot function due to swelling and inflammation, mucus is trapped, and an excellent growth medium for bacteria is provided, resulting in symptoms usually correlating with the location of each sinus. Because the epithelial lining of the sinuses and nasal passage is the same as that seen in much of the respiratory system, sinusitis can also cause problems anywhere in the respiratory tract.

Diagnosis

Although bacteria and viruses account for a majority of cases, allergens, smoke, pollution, and cold air can also cause rhinosinusitis. A careful history can usually elicit the likelihood of the latter diagnoses. Sinusitis is a self-limiting condition 80% to 90% of the time. To avoid unnecessary antibiotic use and expensive testing, clinical prediction rules have been developed on the basis of meta-analyses of numerous studies. According to the Cochrane Database and the Agency for Health Care Research and Quality (AHRQ), the most significant clinical predictors for the diagnosis of sinusitis, regardless of symptom duration, and therefore for the consideration for antibiotics, are unilateral purulence, predominantly unilateral facial pain, bilateral purulence, and the presence of pus in the nasal cavity. When other minor symptoms such as fever, headache, anosmia, facial congestion, fatigue, cough, and dental or ear pain have been present for more than 7 days, antibiotics should also be considered. The use of sinus radiographs and limited computed tomography (CT) scans of the sinuses for the diagnosis of sinusitis should be reserved for recalcitrant cases lasting more than 30 days and/or two antibiotic treatment failures.

Asthma and allergy sufferers can have an allergic rhinosinusitis with symptoms mimicking those of acute sinusitis. If any of the acute sinusitis clinical predictors become evident, then antibiotics should be prescribed. Migraines can often be mistakenly attributed to sinusitis when the main complaint is either sinus pain or headache in the absence of other symptoms. A careful history and physical exam should screen out the athletes with sinusitis.

Treatment

The *Sanford Guide to Antimicrobial Therapy* and most primary care and otolaryngology organizations recommend mucolytics, analgesics, decongestants, and sinus irrigation in the early stages of infection. With athletes who may undergo drug testing, providers should be aware of current banned substances such as pseudoephedrine. A list of these can be found on the U.S. Olympic Committee (USOC) and sports governing board websites. In most cases of uncomplicated acute sinusitis, amoxicillin for 7 to 10 days provides adequate coverage. There is no evidence that non–penicillin-based antibiotics offer any additional benefit over penicillins. In penicillin-allergic patients, sulfa drugs, macrolides such as azithromycin and clarithromycin, cephalosporins, and quinolones are good substitutes, but providers should be aware of the potential tendinopathic side effect of quinolones. In more serious cases or treatment failures, amoxicillin-clavulanic acid for 14 to 21 days is recommended. In athletes diagnosed with sinus infections who have comorbid asthma and allergic rhinitis, nasal steroids may enhance mucociliary clearance and reduce nasal congestion. Aggressive long-term treatment in these athletes with nasal steroids, nonsedating antihistamines, nasal irrigation with saline, and/or leukotriene inhibitors can reduce the frequency of sinus infections and improve lung volumes, fatigue, and overall athletic performance.

Return to Sports

Most athletes with a diagnosis of sinusitis can return to practice immediately. Unless they have a fever, severe fatigue, or a significant symptomatic drop in peak flows, there is no specific reason to hold them out from competition or training. Swimmers and divers with sinusitis, significant eustachian tube dysfunction, serous otitis media, or bilateral facial congestion have increased risk for tympanic membrane rupture and should be watched closely. These athletes also appear to be more susceptible to sinus infections, possibly due to the effect of chlorine as an irritant. A tympanogram to monitor tympanic membrane mobility may be useful in providing clearance to divers with persistent symptoms. Ear plugs are not recommended for water athletes, but nose plugs can be used in athletes susceptible to sinusitis.

James Dunlap

See also Allergies; Infectious Diseases in Sports Medicine; Physiological Effects of Exercise on Cardiopulmonary System

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Skiing, Injuries in

Skiing, an alpine sport and popular winter pastime, is enjoyed in many countries by millions of people at more than 300 facilities in the world's mountainous regions. The skier slides down a naturally or artificially snow-covered hill on skis attached to the foot through boots and bindings. *Telemark skiing* refers to a skiing style and a specific nomenclature in which the only connection to the ski is through a binding attachment of the ski boot at the toes with the heel being free, as is the case with all cross-country skis. The emergence of new technologies and ski designs as well as skiing techniques and interests have led to the further development of alpine or downhill skiing and its numerous sport disciplines, together with cross-country skiing and, most recently, snowboarding, an alternative form in which both the athlete's feet are placed on a single board. The rapid evolution of these sports has been spurred by the innovation and creativity of sport enthusiasts as well as advances in equipment design and manufacture. New disciplines are continually being introduced as the sport continues to develop over time.

Ski Disciplines

The International Ski Federation (FIS) administers the following sport disciplines:

Alpine Skiing. This includes Downhill (DH), Super-G (SG), Giant Slalom (GS), and Slalom (SL). Downhill is considered to be the showcase sports event, with the longest distance and the greatest speed. Downhill and Super-G are considered the speed events, while Giant Slalom and Slalom are considered the technical events. Slalom is the shortest of the tech events, with a zigzag race across the ski hill carving a path around gates. There is also an event termed the Combined (CO; in Europe, K), composed of the combined efforts of two separate races—the Downhill and Slalom—which are run on courses that are shorter than normal. More recently, an event called the Super Combined (SC) was introduced with a shorter downhill and a single slalom, both run on the same day.

Cross-Country Skiing. This is the original and most popular Nordic ski sport. Initially cross-country skiing meant only one technique, in which a "diagonal stride" was performed in prepared ski tracks. In the 1980s, the "skating" technique was popularized and was considered to be more of a free technique than a "classical" stride, in which skiers today use a trackless course except during tricky turns or transitional sections. Cross-country skiing is a rugged mix of endurance and speed, with a variety of race distances ranging from 800-meter (m) sprints to 50-kilometer (km) events.

Nordic Combined Skiing. This is a combination of the two main elements of Nordic skiing, cross-country skiing and jumping. The traditional competition entailed a 90-m jumping competition followed by 15 km of skiing. Ski jumping is one of the most spectacular winter sports because athletes fly through the air traveling distances greater than a football field down a snowy slope.

Freestyle Skiing. This in its earliest form was named for the creative elements and "free" components of skiing performance, which included ballet, moguls, and an aerial maneuver. In 2000, ballet was dropped, and the disciplines of moguls and aerials flourished. In aerials, skiers are launched 50 feet (17 m) or more into the air off a "kicker" to land on a steep slope while performing intricate twists and flips. Moguls is the pulsating sport event where skiers maneuver through a treacherous course of bumps, with two obligatory air jumps that are scored by the judges along with the speed of the run to determine the winner.

Skiing for the Physically Disabled. This gained momentum in the 1960s and was originally called "handicapped skiing." Disabled skiing began as a rehab and recreational activity for people with mobility impairments. Eventually, it also became a competitive environment with disciplines in alpine races and cross-country events. Disabled skiers are classified according to their disability, which includes 12 basic classes along with 3 blind classifications. The FIS uses a 3-class system: sit-skiers, stand-ups, and blind.

Promoting Safety

The United States Ski and Snowboard Association (USSA) is the national governing body of the United States for Olympic Skiing and Snowboarding and is the parent organization of U.S. Ski Team and U.S. Snowboarding.

The promotion of safety and the enhancement of the overall experience for skiing enthusiasts is undertaken by an association called the National Ski Patrol (NSP), which follows a creed of "service and safety." The NSP was originally organized as a committee of the USSA (formerly known as the National Ski Association) back in 1938. In 1980, this nonprofit organization was recognized with a federal charter by the U.S. Congress to promote safety and health in skiing and other outdoor winter recreational activities. Today, its membership exceeds 26,000, with more than 600 ski patrols throughout the United States. NSP has evolved from its infancy as a service organization to a professional education association responsible for the development of, and education in, safety and emergency care training methods.

Although skiing and snowboarding are commonly depicted as highly dangerous, deaths associated with the sport are rare. During the period from 1991 to 2003, a total of 469 traumatic deaths occurred at ski resorts in the United States. Collisions of all sorts, but chiefly with trees, account for 90% of the fatalities.

The issue of helmet use in skiing and snowboarding continues to be debated. Helmet use is currently accepted by approximately 38% of skiing enthusiasts but has been steadily on the rise at a rate of nearly 4% annually. Although helmet use has been shown to reduce the number of head injuries by 30% to 50%, this is limited to less serious injuries. Non–helmet users' risk of death from head injuries is two times greater than the risk for those involved in accidents while wearing helmets. In very high-speed collisions, helmet use has not resulted in a reduction of fatalities because helmets are not designed to encounter the extreme forces involved at high speeds.

Orthopedic Ski Injuries

The most common injury in skiing is attributed to the knee joint. Injuries to this particular joint are typically identified as soft tissue and ligamentous type injuries, with the anterior cruciate ligament (ACL), the ligament inside the knee joint that prevents anterior displacement, being the most commonly injured tissue. An injury to this ligament is typically the result of a fall that causes a distribution of forces and an increase in the torque absorbed by the knee. The ski itself acts as a lever arm that significantly increases these forces transmitted through the knee during a fall. This is why proper equipment and maintenance of ski bindings are essential. It is important that the binding-release mechanisms activate during a fall to prevent significant injury to the knee.

The medial collateral ligament (MCL), which is the supporting ligamentous structure on the inside aspect of the knee, and the meniscus, the cartilage tissue inside the knee joint, are the next commonly damaged tissues in the lower leg. The ACL and the meniscus are typically repaired with surgical intervention to prevent long-term consequences to the knee joint. MCL injuries are not typically treated surgically but require a rehabilitation intervention strategy for full recovery. The relative frequency of lower leg fractures continues to decline, which can be attributed to better equipment, better binding technology, and shorter skis, particularly the shorter tail on carving skies, which has revolutionized the recreation industry.

Injuries to the head and face are typically the next most common in skiing. Concussions and contusions acquired when a skier falls and comes into contact with the snow surface at significant forces result in a higher frequency of reported trauma. Fractures of the skull and closed-head injuries are the most frequent traumas that result in head-related traumatic deaths. Attention to concussions and any mild traumatic brain injuries is essential to recovery so that the athlete does not return to the sport before proper recovery has been confirmed. Many head injuries are complicated by the fact that they recur over the course of a day or an entire ski trip, leading to complications and long-term consequences. Another frequent injury to the facial region is due to t-bars and poles and accidents that occur while getting on and off lifts. This includes facial cuts, knocked-out teeth, bloody noses, eye injuries, and ear cuts or abrasions following contact with the snow.

Upper extremity injuries in the skiing population occur much less frequently than in the snowboarding population. Most commonly, typical injuries reported in the literature include fractures of the wrist and forearm as a result of falling on an outstretched limb. Shoulder dislocations predominate for the same reason but more typically to an outstretched arm reaching backward. The shoulder essentially becomes unstable and pops out of joint completely. A dislocation is quite different from a shoulder separation because it involves the shoulder joint (known as the *glenohumeral joint,* the articulation of the head of the humerus with the glenoid fossa of the scapula) and requires a much greater traumatic force for injury to occur. A dislocation is different from a subluxation because the joint actually displaces completely—it doesn't just slide to the edge of the rim and return to its normal position. A separation usually involves the *acromioclavicular (AC) joint,* a supporting structure at the end of the clavicle.

The so-called *skier's thumb* is caused by injury that results when a ski pole and, more conspicuously, the wrist strap force the thumb away from the axis of the hand, resulting in a ligamentous injury. There are two common strap grips, the traditional and the saber, resulting in injury because the thumb cannot get out of the way during the fall, causing trauma to the ulnar collateral ligament of the thumb. This ligament connects the bones on the inside aspect of the thumb (more specifically the metacarpal and the proximal phalanx) and is typically the most commonly injured extremity next to the knees, which are sprained. Because it plays a major role in our grasping, pinching, and stabilizing objects in our hand, the injury is often very debilitating. Typical treatment following proper evaluation and diagnosis is immobilization for up to 6 weeks in less traumatic situations. In severe cases, however, surgery is recommended to repair the injured ligament. The best prevention strategy would be to use strapless poles so that one falls on the palm of the hand rather than a thumb-restricted hand with a pole in between. Fractures of the lower arm are also common, including fractures to the radius, the ulna, and the scaphoid bone in the hand.

Spinal injuries are not very common, but they still account for almost 5% of the fatalities that occur on the slopes. Injuries to the cervical spine are the most traumatic. Cervical vertebrae may be fractured as the result of a fall, whether it be due to compression, rotation, or hyperextension. Such injury potentially results in damage to the spinal cord, which is life threatening.

Nonorthopedic Ski Injuries

Other common skiing injuries that are less serious but still debilitating include frostbite, dehydration, and sunburn. Sunburn results from solar ultraviolet (UV) radiation, not from the heat. Sun exposure on cold, snowy days without any protection often results in sunburn, particularly in young children. It is essential that prevention be emphasized while skiing anytime. Hypothermia results when the core body temperature drops below 95 °F. Exposure to cold environments, particularly in the presence of wet, windy conditions, can lead to the loss of body heat very quickly. Recognizing the signs and symptoms, such as confusion, slurred speech, fatigue, exhaustion, shivering, and loss of motor control, necessitates immediate action. The key is to eliminate the exposure and warm the individual. Hypothermia may lead to cardiac arrest; therefore, close observation is extremely important. Frostbite is literally frozen body tissue. Children are at a much greater risk than adults because they lose body heat more rapidly and are reluctant to protect against exposure. Treatment typically includes removing the wet clothing and warming the exposed body parts in warm—not hot—water and prevention from additional exposure. Following an appropriate immediate treatment strategy, medical care is advised.

Preventing Ski Injuries

There are several ways to prevent serious injuries as a skier. This includes maintaining your equipment every season by having a certified ski technician service your skis and bindings every year. Proper binding release and new advances in binding technology are the main reason for ski injuries declining. The skier should always make sure that his or her boots fit properly. Use of protective eyewear and a helmet is recommended. One of the best ways to prepare for the upcoming ski season and to prevent injury on the slopes is to maintain a strength-and-endurance exercise program. Skiing requires aerobic power and strength, even at the beginning of the season; trying to "ski oneself into shape" is not recommended. Some strength exercises that will prove useful are leg presses, squats, hamstring curls, lateral leg raises, and core exercises such as crunches, sit-ups, and side bends. For enhancing aerobic capacity, cycling with the seat adjusted high at >80 revolutions/minute (rpm), running, swimming, and using a jump rope, ski machines, stepping machines, and elliptical trainers are recommended.

Richard Quincy and Grant Armour

See also Conditioning; Frostbite and Frost Nip; Snowboarding, Injuries in

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Skill Acquisition in Sports

Humans acquire skills, sometimes deliberately, sometimes incidentally, and often by necessity. Skill can be defined as the achievement of an intended outcome repeatedly, with economy of both time and effort (which is logical, given that conservation of energy has been the primary driver in the evolution of most organisms). In sports, acquisition of skill can refer to movement (learning specific ways in which to move in order to achieve a movement goal) or the cognitions associated with movement (e.g., learning when and where to move). In both instances, the "skill" shows improvement as a function of appropriate practice, accompanied by increasingly consistent performance associated with greater persistence and, eventually, adaptable performance in a wide range of situations or contexts.

Our understanding of skill acquisition has its beginnings in work that examined the way in which people acquire telegraphy skills—the ability to transmit and translate the complex dots, dashes, and pauses of Morse code—which was the Internet of the 1800s. The work established that it takes many years of training to become truly skilled, variability of performance decreases over time, and events that disrupt the performance of beginners are less likely to disrupt the performance of experts. The work also suggested that skill acquisition is not necessarily continuous but that plateaus can occur, during which practice does not appear to take effect. Shortly afterward, a universal law of learning was realized. This was the power law of practice, which characterizes skill acquisition as having the greatest rate of change early in practice, with gradual reductions in rate of change occurring as a function of increasing amounts of practice. The role of practice in skill acquisition has received much consideration, not surprisingly given the remarkable feats of skill so often seen in sport. While it is unlikely that there will ever be a definitive clarification of whether those of us who display such high levels of skill are a freak of nature or the function of nurture, there is no doubt that the level of skill that most of us achieve is closely associated with the degree to which we devote time and effort to practice the skill.

Two approaches dominate the study of skill acquisition in sport: information processing approaches and ecological-dynamical approaches.

Information Processing Accounts of Skill Acquisition

The information processing approach to skill acquisition evolved from cognitive psychological characterizations of the human brain as a computer that processes data from the stream of information elicited by the sensory organs and produces an output specific to the "software" that has been loaded. The approach supposes that the flow of information from our senses is of no value until it is converted to symbolic representations that guide movement with commands that are programmed either in advance as some sort of movement plan or schema (open-loop models) or modified on the basis of comparing available afferent information with central representations of the sensory feedback generated by previous successful movements (closed-loop systems).

The approach implies that repetition allows the internal representations to be updated, adapted, and refined (e.g., with knowledge of the results) to produce increasingly efficient movement that progresses from a consciously controlled, cognitive stage of information processing that is rule based, slow, and erratic to an unconsciously controlled, automatic stage that is procedural, fast, and effortless. This fundamental, stages-of-learning distinction is common across the numerous psychological theories of skill acquisition. Recently, it has been argued that the cognitive stage may be superfluous to motor learning and that the learner does not therefore need to progress through such a stage before reaching later autonomous stages that reflect expert performance. It has even been suggested that advantages accrue from avoiding the cognitive stage. By using *implicit* motor learning techniques that prevent the accumulation of explicit or declarative knowledge during the cognitive stages of skill acquisition, researchers have trained people in skills that are more stable under conditions of psychological stress, multitasking, and even fatigue.

Ecological-Dynamical Approaches to Skill Acquisition

An ecological approach to skill acquisition grew out of dissatisfaction with the view that there is a need to process information from the senses before movement can be produced efficiently. In *The Ecological Approach to Visual Perception,* J. J. Gibson (1979) argued that the direct interaction between an organism and its environment specifies *affordances* (the personal possibilities for an action or behavior); information obtained by perception, therefore, does not require elaboration in the manner suggested by information processing accounts, implying that movements can be initiated directly by perception and that perception and action are mutually dependent.

Coupled with the ecological approach, a dynamical systems view of motor behavior has emerged that views biological organisms as capable of dynamically self-organizing in response to constantly interfacing with their environment, much in the way that the study of thermodynamics deals with open systems that self-organize into spatial and temporal patterns that can be defined by one or two specific order parameters.

This view progressed from the work of N. A. Bernstein, who in his book *The Coordination and Regulation of Movement* (1967) suggested that the human body (the motor apparatus) has evolved with an almost limitless array of coordination possibilities to respond with dexterity to the host of motor problems that constantly emerge in the environment. Bernstein viewed skill acquisition as a degrees-of-freedom problem in which the learner must find a way to coordinate the many degrees of freedom available within the motor system. He suggested that this is done by constraining the muscles to act as synergies (i.e., coordinative structures) that can be controlled without cognition. Initially, this requires execution of the movement/skill to be simplified by freezing some of the degrees of freedom (i.e., by locking up various joints) and releasing the degrees of freedom as movement competence proceeds and later by exploiting the energetic forces that exist within the actor-environment interface (e.g., inertia, momentum). This focus on movement constraints within an ecological framework that models the human movement apparatus as a dynamic system attracted to a stable coordination pattern offers an alternative to the traditional information processing approach to skill acquisition in sports.

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See also Attention Focus in Sports; Sport and Exercise Psychology

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Skin Conditions in Wrestlers

No other sport is probably more closely associated with skin lesions and infections than the sport of wrestling. Because wrestling involves direct contact, the chances of transmission to an athlete are higher than in most sports. Transmission can occur most obviously by skin-to-skin contact, but can also be spread by contact with objects such as a mat or headgear. While skin infections were once considered a nuisance, they can now be deadly or debilitating, and their proper identification and treatment have never been more important. As discussion of every skin condition seen in wrestling is beyond the scope of this article, the most common conditions seen in the sport are addressed here.

Bacterial Infections

Impetigo

The most common bacterial infection seen in wrestling is impetigo. The bacteria usually responsible are *Staphylococcus* or *Streptococcus*. The bacteria are spread from person to person or by shared equipment or surfaces. The most common place to see impetigo is in areas where the skin is exposed. Honey-crusted lesions that are often seeping fluid characterize the disease. The area around them may be red, and the patient may have itching. The infection is highly contagious. When the condition is discovered, the athlete should be removed immediately from competition. A culture can definitively identify the organism, but diagnosis is often based on the uniqueness of the lesion. Treatment consists of topical antibiotics for small lesions and oral antibiotics for larger patches of lesions. Return to sports is generally after 5 days of antibiotic treatment, and when all the lesions have dried and crusted over. They should also be covered with a gas-permeable bandage.

Folliculitis

Folliculitis is a common term referring to infection of the hair follicles by bacteria. It often occurs after a wrestler suffers an abrasion from the mat or from clothing. Small, pus-filled follicles characterize the infection. Treatment is imperative to prevent secondary infection. Topical antibiotics are often prescribed to treat this infection. A gas-permeable dressing should cover the affected area while the athlete is actively infected. In most instances, athletes do not need to be removed from competition when suffering from folliculitis.

Furunculosis

Furunculosis is a form of folliculitis in which a “boil” develops. The bacteria usually responsible for this infection are *Staphylococcus* or *Streptococcus*. Again, it commonly occurs from an abrasion from the mat or from clothing. It is characterized by a large, red, often pus-filled raised lesion on exposed areas of the skin. Topical and, if warranted, oral antibiotics are used to treat this infection. If pus is present, often physicians will open the lesion and allow it to drain while the patient is being treated with antibiotics. If the lesion can be adequately covered, there is no pus drainage, and the athlete does not have any ill effects from the lesion, then he or she can participate in sports during treatment.

Methicillin-Resistant Staphylococcus Aureus

The emergence of methicillin-resistant *Staphylococcus aureus* (MRSA) has become a great concern in wrestling. These bacteria are resistant to some of the most common antibiotics prescribed for skin infections. MRSA is often believed to start as a lesion that looks like a “spider bite” or boil. It is often a raised, red lesion that may or may not have pus at its center. If not identified and treated quickly, the infection can advance through a limb or disseminate through the body. If this happens, patients may have some of the typical signs of systemic infections, including a fever and chills. Identification of the bacteria can be done via a culture. Treatment includes opening and drainage of the wound followed by antibiotic therapy. More general antibiotics are given first and tailored to drugs that the MRSA is susceptible to once the bacteria are identified and susceptibility to antibiotics is determined via culture. Treatment is begun with a high suspicion of MRSA infection before the cultures are returned. Again, return to sports is allowed when all the lesions have dried and crusted and any systemic symptoms have resolved after antibiotic treatment. Some patients, however, are chronic carriers of MRSA. Doing swabs of the nasal passages, groin, or axillae, where MRSA is known to colonize, often leads to their discovery. These patients are often placed on antibiotics, either topically or orally, to try to definitively eradicate the infection.

Acne Vulgaris

Athletes are not immune to acne vulgaris, one of the most common bacterial infections found in the general population. Acne vulgaris is caused by bacterial growth in the pores of the skin secondary to androgen stimulation that results in unorganized keratinization and irritation of the skin. Stress, both mechanical and emotional, as well as certain drugs, cosmetics, and foods, can make the acne worse. Acne is typified by the blackheads and whiteheads on a red base seen most commonly on the face but also found on any surface of the body. The acne lesions are often characteristic, and no further laboratory work-up is needed to identify the condition. Acne is treated using topical bactericidals, topical and oral antibiotics, topical and oral retinoids, hormonal treatments, phototherapy, or laser therapy. These treatments may be carried out alone or in combination to try to control the outbreaks. It is critical to try to control these outbreaks to prevent secondary bacterial infection in wrestlers with more severe cases of acne. Acne alone is not reason enough to stop a wrestler from competing. Acne can be lessened by wearing clean, dry, loose, cotton clothing in a cool, well-ventilated environment. Wet clothing should be changed as soon as possible. Proper-fitting equipment is also necessary as acne can be made worse by ill-fitting equipment. Scarring from continued irritation of areas of acne is often a complication of this common athletic skin condition.

Viral Infections

Herpes Simplex

The most common viral infection seen in the sport is herpes simplex. In wrestling, this infection is often referred to as herpes gladiatorum. The virus that is often responsible for this disease is herpes simplex I. This virus is spread in the same manner as bacteria, but the infection is not treatable with antibiotics. The lesion from herpes simplex is described as a "blister on a red base." It is often seem in the area of the lips but can appear anywhere on the body. There are often systemic symptoms that occur approximately 1 week before the eruption of the lesions, which include flulike symptoms, malaise, fatigue, and itching or tingling at the site of the infection. The virus can be identified by a culture, but this is usually not performed as the lesions are so specific to this virus. Treatment is often supportive and addresses individual symptoms. If identified early, antiviral medicines can be given that can decrease the symptoms and duration of the outbreak. These drugs work best if given within 72 hours of identification of the virus. Wrestlers with chronic infections are often placed on oral antiviral medications. Return to sports occurs when all the lesions have dried and crusted over. This can take anywhere between 4 and 7 days. The lesions should then be covered with a gas-permeable bandage for competition.

Molluscum Contagiosum

Molluscum contagiosum is another common viral infection seen in wrestlers. It is spread in the same manner as the other viral infections. Wrestlers who are infected should immediately be removed from competition. Raised lesions with a hollow center characterize the disease. They are often seen in clusters and have a waxy appearance. They are often found on exposed areas of the skin. Treatment is by removal of the lesions via modalities such as freezing with liquid nitrogen or scraping off using a specific tool. There are also medications that can treat the disease. Once the lesions are removed and the athlete is free of new lesions, the wrestler can return to activity.

Warts

Warts are caused by the human papillomavirus and can be found on any part of the athlete. They are characterized by raised, scaly lesions and are often characteristic in their appearance. They are spread by direct contact. There is usually no laboratory testing attempted as the lesions themselves are diagnostic. Treatment is via removal of the lesions by substances such as salicylic acid or liquid nitrogen or by direct excision. As long as the lesions are covered, wrestlers need not be removed from competition.

Fungal Infections

Tinea

The most common fungal infection is due to the tinea fungus. Tinea can be found in any location on the body and thrives in a warm, moist environment. Infection in the scalp is referred to as *tinea capitis.* Infection at the foot is referred to as *tinea pedis,* or athlete's foot. Infection in the groin is referred to as *tinea cruris,* or jock itch. Infection on the trunk or extremities is termed *tinea corporis,* or ringworm. The most commonly isolated organism causing infection is *Trichophyton tonsurans.* These infections are spread by skin-to-skin contact and by sharing of equipment, uniforms, or towels.

A ringworm infection is most often recognized on the body by its characteristic ring formation. The fungus generally appears in a red patch that is scaly and has a distinct border with a clear center. This patch generally does not have little "satellite" lesions around it but can appear on other areas of the body. A scraping of the fungal infection can allow its identification when it is observed under a microscope; however, this is rarely done as the lesion often has a characteristic appearance. Athletes discovered with these lesions should be immediately withdrawn from competition as the infection is highly contagious. Tinea lesions are also likely to get secondarily infected with bacteria if left untreated. Treatment is generally by topical antifungal medications. If topical antifungal medications cannot control and treat the infection, then systemic antifungal medications are used. Caution needs to be used when these are prescribed as they may be toxic to the liver. Some athletes who are highly susceptible to tinea and develop chronic infections are often placed on chronic antifungal medications. Return to sports should not be attempted until after approximately 5 days of treatment with antifungal medication and drying of the lesions. These should be covered with a gas-permeable bandage when returning to competition.

Infestations

Scabies

Scabies is caused by an infestation of the body by a small living organism. The living organism burrows itself in the skin, leaving droppings along the burrows, causing persistent itching. The hallmark symptom of infestation is a persistent itch followed by redness of the affected skin. This is often first seen in the skin between the fingers but can also be seen in other areas of the body. The rash is identified by the characteristic burrows. This skin condition is easily spread from person to person. Usually, the athlete is not the only person affected as he or she brings the infection home, causing the infection of other family members. Treatment is washing with a solution that is left on overnight to kill the organism. Treatments are carried out every 3 days until the infection is cleared. Individuals without symptoms are treated twice, with 1 week between treatments. Athletes should be removed from competition at the first signs of infestation and can return to sports the next day after the overnight treatment.

Noninfectious Skin Conditions

Contact Dermatitis

This skin condition is not due to an organism but is due to an allergic reaction to an object such as a headgear. The skin lesion generally begins as a red patch with a border that approximates the size of the item exposed to the skin to which the athlete is allergic. This redness may evolve to scaling and weeping of the area with continued exposure. Small fluid-filled blisters may also appear. There are no lab tests to perform as the skin signs usually alert physicians to the diagnosis. Treatment is by using topical corticosteroids on the affected areas. If the outbreak is significant, oral steroids may be necessary. There is often no reason to withdraw the athlete from competition. The key to treatment is to eliminate that item to which the athlete is allergic, substitute the affected item with an item the athlete is not allergic to, or put a barrier between the irritating item and the athlete's skin.

Prevention

Good hygiene is the key to prevention of common dermatological conditions associated with wrestling. The following rules should be followed:

1. Removal from competition at the first sign of an infectious lesion.
2. Showering after all practice and competition sessions.
3. Thorough drying of all body areas.

4. No sharing of equipment or uniforms.
5. Use of breathable athletic clothing.
6. Consistent laundering of athletic clothing.
7. Consistent cleaning of athletic surfaces.
8. Being aware that body shaving exposes the skin to infection.

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See also Fungal Skin Infections and Parasitic Infestations; Skin Disorders Affecting Sports Participation; Skin Infections, Bacterial; Skin Infections, Viral; Wrestling, Injuries in

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Skin Disorders, Metabolic

Metabolic skin disorders include several conditions that may cause discomfort and impaired performance. Conditions such as eczema, psoriasis, and urticaria can affect a significant proportion of the athletic community. The pathophysiology of all these disorders can be traced back to the participant's immune system working abnormally. Although treatment of these skin problems is not difficult, they must be first correctly identified and diagnosed to enable the timely return of the athlete to active participation.

Eczema

Eczema is an extremely common skin condition and has the potential to affect athletic participation. Although *eczema* is often used synonymously with the term *atopic dermatitis,* true eczematous reactions can occur in people with or without other findings of atopy, such as allergic conjunctivitis, bronchial hyperreactivity, or allergic rhinitis. Nonallergic sources account for 10% to 25% of eczematous reactions, and most are associated with atopy. In recent years, the term *atopic eczema/dermatitis syndrome* was coined to encompass several varieties of atopic dermatitis that are clinically related.

The effect that eczema has on athletes is a function of its prevalence in the population. Up to 10% of school-age children in the United States have eczema; furthermore, many school-age children participate in organized athletics. As a result, there is a significant likelihood that school-age children who play sports will also have eczema.

Diagnosis

Diagnosing eczema is a challenging task because of the many noneczematous disorders that mimic its skin lesions and symptoms. In addition, the skin manifestations of eczema itself are varied, appearing erythematous, papular, macular, or pruritic depending on its severity. Milder lesions are characterized by erythematous, maculopapular microvesicles. More severe outbreaks display crusted-over lesions that may or may not weep. Over time, the lesions become increasingly dry and result in lichenification. Regardless of the lesion's severity or chronicity, the hallmark of eczema is the intense pruritus (itching) that accompanies the rash and often results in excoriation due to repetitive scratching.

Eczema is usually localized to the flexor creases of the arms and legs, with occasional distribution to the genitalia and face. However, as the condition becomes more severe, it may spread to any body surface.

Treatment

Most cases of mild eczema will respond to more benign treatments such as topical steroid creams or over-the-counter moisturizing lotions. Caution should be advised with chronic topical steroid use,

Eczema

Source: From DermNet NZ. Reproduced with permission.

since there is risk of pigmentation changes, striae formation, and atrophy of the skin. Because of these complications, treatment with steroid creams around the eyes and face should be avoided. Pruritus that is associated with eczema is usually well controlled with antihistamines.

Newer therapies aimed at suppressing the immune response, such as cyclosporine, have also been used. In recent years, the medication pimecrolimus has been marketed as a first-line agent against mild to moderate eczema. Although this nonsteroidal medication is effective in inhibiting the inflammatory cytokines of eczema, physicians should attempt to use more conventional treatments first, because pimecrolimus suppresses T-cell function and may make individuals more susceptible to viral infections.

Return to Sports

Eczematous eruptions can be a significant impairment for athletes. The discomfort of not only the pruritus but also the physical contact of athletic gear against the affected skin can negatively affect athletic performance. Furthermore, the team physician must recognize the risk of secondary bacterial infection of eczematous skin, usually caused by *Staphylococcus aureus* or Group A beta-hemolytic *Streptococci*. It is this secondary bacterial infection in eczema that may require withholding the athlete from participation, especially in sports that require skin-to-skin contact between competitors.

Return-to-play decisions must be individualized based on a number of considerations. The location of eczematous outbreaks on the body and the feasibility of covering the lesions, clinical improvement with treatment, and the likelihood of physical contact between athletes should all be factors in determining an athlete's return. Because misdiagnosis and/or ineffective treatment of eczema are a common occurrence, habitual return to play after immediate initiation of antibiotics should be discouraged.

Psoriasis

Psoriasis is an autoimmune condition that affects approximately 2% of the U.S. population. It is characterized by erythematous, scaly patches that are sometimes silvery in color. The patches usually have very well-defined edges and often appear symmetrically on the body. As with eczema, the performance of athletes afflicted with this disorder is often impaired because of the discomfort of the rash, the chronic arthritis associated with the condition, or secondary bacterial skin infections, which may preclude participation in sports.

Diagnosis

The key to diagnosing psoriasis is being able to identify its pathognomonic rash from other dermatologic conditions. Psoriatic lesions are usually covered with a silvery white scale as a result of the increased turnover of the skin cells. Although this appearance is unique to psoriasis, it may not always manifest in this way and can easily be misdiagnosed as eczema, dermatophytic infection, or lichen planus.

Athletes with psoriasis may display the Koebner phenomenon, in which psoriatic plaques appear on previously unaffected areas as a result of trauma. This may be especially disabling for athletes if the affected site is the plantar surface of the foot. Although this phenomenon waxes and wanes with athletic activity, it may become uncomfortable enough to discourage an athlete from participating in sports.

Another complication of psoriasis that may affect athletes is psoriatic arthritis. This chronic manifestation affects about 5% of patients with psoriasis. Classically, the axial skeleton and the metacarpophalangeal (MCP) and proximal interphalangeal

Psoriasis

Source: From DermNet NZ. Reproduced with permission.

Notes: The most common ages for psoriasis to first appear are the late teens, but it is possible for children to be affected as well. It affects men and women equally, although among children, girls are more commonly affected than boys. There does appear to be a genetic predisposition to psoriasis, but it is also known to be influenced by many environmental factors. Usual sites of involvement include the scalp, eyebrows, knees, elbows, ears, genitalia, and nails. Psoriatic fingernails can become yellowish in color and display pitting, which can often aid physicians in diagnosis.

(PIP) joints of the hands are involved. On X-ray, erosion of the articular surfaces of the involved joints is observed.

Treatment

There is a wide spectrum of agents used to treat psoriasis. The more traditional methods such as selenium formulations, topical corticosteroids, or coal tar preparations are effective against mild cases of psoriasis.

As the psoriatic outbreak becomes more severe, the use of systemic or newer biologic agents may be indicated. Although quite effective, these newer medications and treatment modalities carry a certain degree of risk. Methotrexate is hepatotoxic and has been shown to interact with nonsteroidal anti-inflammatory drugs (NSAIDs). Cyclosporine combined with psoralen-ultraviolet light treatment (PUVA) increases the risk of squamous cell carcinoma. Oral retinoids have been shown to be highly teratogenic. Thus, the team physician may decide to take the help of other specialists in prescribing these agents and managing more severe cases of psoriasis in athletes.

Return to Sports

Return-to-sports decisions regarding outbreaks of psoriasis are quite similar to those regarding outbreaks of eczema. The risk of secondary bacterial infection is present in psoriasis, and decisions regarding return to play should take into account the same precluding factors as those concerning eczema. Therefore, the team physician should determine the appropriate time for return to competition on a case-by-case basis.

Exercise-Induced Urticaria

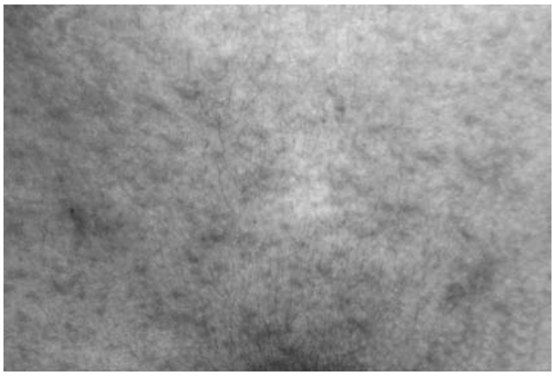
Exercise-induced urticaria, also known as *cholinergic urticaria*, is a physically mediated allergic condition that has been increasingly reported in recent years. This type of reaction occurs much less commonly than those arising from allergen exposure; however, for active individuals and athletes, this disorder may be extremely debilitating.

Diagnosis

The physiologic mechanism underlying exercise-induced urticaria is unknown, although the clinical manifestations appear to arise due to an exaggerated cholinergic response to rapid increases in core body temperature. Acetylcholine release followed by mast cell degranulation and histamine release precede the urticarial response. People with this condition may experience the urticaria not only after exercise but also after hot showers, during times of emotional stress, or when afflicted with a fever.

The classic response is characterized by the development of generalized flushing, coupled with discrete, punctuate, extremely pruritic 2- to 4-mm wheals surrounded by a red flare. Fortunately, vascular collapse is not commonly associated with this condition. Other clinical signs of parasympathetic activation such as lacrimation, salivation, or diarrhea may also aid in diagnosis.

Urticaria usually begins approximately 6 minutes after the onset of exercise and reaches a peak in 12 to 25 minutes. However, recovery may take from 2 to 4 hours. This condition primarily affects young active individuals between the ages of 10



Exercise-induced urticaria

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and 30, although it may recur for many years after initial onset. Although diagnosis is usually made clinically, methacholine skin challenge tests have been used to help confirm the presumed diagnosis.

Treatment

Treatment of cholinergic urticaria consists of withdrawing the precipitating factor and using antihistamine medications/creams to relieve the urticaria. Use of a mast cell–stabilizing medication such as cromolyn sodium or beta blockers such as propranolol has also been reported, but antihistamines such as hydroxyzine are more universally recommended.

Return to Sports

The degree of discomfort and willingness to return to participation dictate the decision to allow an athlete to continue playing. However, if exercise is the essential trigger of the condition, it may be prudent to withhold the player from participation until prophylactic antihistamine medications can be given to help blunt the urticarial response.

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See also Dermatology in Sports; Skin Conditions in Wrestlers; Skin Disorders Affecting Sports Participation; Urticaria and Pruritus

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Skin Disorders Affecting Sports Participation

Sports-related skin disease is quite common with a wide variety of causes. Broadly categorized as infections, dermatitis, or trauma, several skin disorders directly affect sports participation. Early recognition and treatment are crucial in determining the athlete's ability to return to play and preventing the occurrence of outbreaks among team members.

Infections

Skin infections cause the most disruption to individual and team activities. Many of the skin infections that affect athletes are transmitted by close contact. A variety of other factors contribute, including macerated skin from sweating, abrasions, and occlusion from equipment. These risk factors are present in many sports. The National Federation of State High School Associations Sports Medicine Advisory Committee and the National Collegiate Athletic Association have set specific guidelines for return to sports after a skin infection is diagnosed in wrestlers; these guidelines can help guide treatment and return-to-play decisions for other sports as well. Athletic skin infections can be fungal, bacterial, or viral.

Fungal Infections

Fungal infections of the skin are caused by dermatophytes that invade and reproduce in the outermost layer of the skin, as well as the hair and nails. They cause superficial infections commonly referred to as "ringworm" or *tinea.* Tinea affects the scalp, body, groin, and feet. Fungal infections are easily spread between athletes. Therefore, an athlete should have the affected areas covered and oral or topical antifungal treatment initiated. Wrestlers specifically need to be treated for a minimum of 72 hours for the skin and 2 weeks for the scalp prior to return to play.

Bacterial Infections

Bacterial disease can range from impetigo to cellulitis. Impetigo appears as a honey-colored scab and is caused by *Staphylococcus* or *Streptococcus* bacteria. Treatment should be initiated after soaking the area to remove the lesion's crust. Topical antibacterial agents are then applied for localized disease. Oral antibiotics are considered if the disease is extensive or if methicillin-resistant *Staphylococcus aureus* (MRSA), a serious condition, is suspected.

Boils (abscess) typically begin near the hair follicles. Infection is introduced by skin injury and is typically caused by *Staphylococcus* or *Streptococcus.* Abscesses, typically described as painful, red, soft tissue masses, most commonly occur in moist areas where hair follicles are present, such as the groin, posterior thighs, and face. Athletes at risk include those who are diabetic, are obese, use steroids, or have poor hygiene. Treatment consists of draining the lesion. Oral antibiotics are not typically needed unless there is concern for overlying skin infection (cellulitis) or MRSA. Cellulitis presents as diffuse red, warm, tender, and swollen areas of skin. Cellulitis is particularly dangerous as it may spread rapidly. Athletes with the condition can become quite ill. Antibiotic treatment and close monitoring are crucial until resolution.

Bacterial infections need to be considered "noncontagious" prior to return to play. This requires that no new lesions develop for 2 days. All current lesions should be scabbed over, with no oozing or drainage. An athlete needs to have been on an oral antibiotic for a minimum of 3 days. If new lesions develop or there is continued drainage, a diagnosis of MRSA should be considered, which requires prolonged treatment, defined as a minimum of 10 days, with all lesions scabbed over.

Viral Infections

Viral disease can take many forms, but most frequently, athletes are plagued by the herpes simplex virus (HSV). HSV appears as a cluster of skin blisters with a reddened base. Athletes may have associated symptoms such as a fever, chills, and muscle aches. Patients often notice a tingling or burning sensation before the onset of HSV lesions. Athletes with abrasions or lacerations of the skin are at high risk for transmission. HSV is self-limiting and will spontaneously improve but can recur and is easily spread. Outbreaks can be prevented by keeping athletes out of competition while treatment is initiated. A low index of suspicion and early detection are crucial for preventing spread. Careful inspection of each athlete before practices and competitions is vital to prevention. Prior to returning to play, the athlete should have no new lesions for 2 days, and all current lesions should be scabbed over, with no oozing or drainage. An athlete's first episode of herpes needs to be managed with antiviral treatment for a minimum of 10 days. This should be extended to 14 days if associated symptoms such as a fever, chills, and muscle aches are present at diagnosis. Recurrent episodes require a minimum of 5 days' antiviral treatment prior to return to play. In athletes with a recurrent infection, suppressive treatment should be considered.

Molluscum contagiosum is caused by the poxvirus and is spread by skin-to-skin contact. This infection is typically seen in swimmers, gymnasts, and wrestlers. Molluscum appears as a skin-colored papule with a central dimple, commonly seen on the face, neck, and trunk. These lesions are usually asymptomatic and resolve spontaneously. However, spontaneous resolution can take many months, and most athletes desire to expedite resolution in order to return to play. Molluscum can be removed by scraping, cryotherapy, or local application of medicated creams.

Parasitic Infections

Scabies is caused by *Sarcoptes scabiei.* A scabies infection occurs when a female mite burrows under the skin, leaving eggs in the tract she creates. Scabies infections are characterized by severe nighttime itching that usually occurs between 1 and 4 weeks after infection. Burrows appear as tracts in the skin and are commonly found between the web spaces of the fingers or over the wrists, breasts, axillae, scrotum, penis, or knees. Transmission occurs through close contact for a substantial period of time. Treatment typically involves a topical lotion. The lotion is spread over the entire body, kept on for 8 to 12 hours, and then washed off. A repeat application in 1 week is usually adequate for eradication. The clothing and bedding of the infected individual should be washed and dried at high temperatures. Household contacts of those infected with scabies should also wash their clothing and bedding and be treated as noted above.

Infection Prevention

In athletes, skin infection prevention is crucial. This requires athletes to pay close attention to personal hygiene, such as not sharing personal items or equipment, washing clothes and personal gear regularly, showering immediately after practice and competition, and regular use of shower shoes. Education and skin surveillance are essential for early recognition and treatment and to expedite return to play.

Dermatitis

Allergic or irritant dermatitis can cause significant redness, swelling, and itching of an affected body part. Diagnosis is often readily apparent in individuals on the basis of the distribution of the rash and a history of repeated skin eruptions after exposure. Recognition of environmental irritants and allergens is critical for appropriate treatment.

Trauma

Abrasions need to be cleansed with antibacterial soap, and protective dressings need to be applied. Return to play for lacerations should occur once active bleeding is stopped and the wound is properly dressed. Calluses and blisters occur secondary to shearing forces and perspiration. Frequently due to ill-fitting footwear, treatment of these conditions involves frequent sock changes, antiperspirants, and new, properly fitted shoes. Similarly, jogger's toe is caused by painful bleeding beneath the toenails in an athlete wearing improper shoes. Properly fitted shoes again are the mainstay of treatment.

Matthew Leroy Silvis and Amy Sucheski

See also Allergic Contact Dermatitis; Cholinergic Urticaria; Fungal Skin Infections and Parasitic Infestations; Jogger's Nipples; Prickly Heat; Skin Disorders, Metabolic; Skin Infections, Bacterial; Skin Infections, Viral; Skin Infestations, Parasitic; Sunburn and Skin Cancers; Toenail Fungus

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Skin Infections, Bacterial

Bacterial skin infections are a common occurrence among athletes and range from simple "sweaty-sock syndrome" to potentially life-threatening methicillin-resistant *Staphylococcus aureus* (MRSA) infections. Conditions that favor infection, such as skin abrasions, moist environments, and skin contact with other players, are all present in the athletic environment. This entry discusses some common and some unusual causes of bacterial skin infections among athletes.

MRSA Infections

There is a growing prevalence of this infection in the athletic community, and although deaths are extremely uncommon, they have been reported. The hallmark of these infections is that they do not respond to the antibiotics traditionally used for skin infections and may progress more rapidly than do "normal" skin infections to severe illness requiring hospitalization. It is important to distinguish between hospital-acquired methicillin-resistant *Staphylococcus aureus* (HA-MRSA) and community-acquired methicillin-resistant *Staphylococcus aureus* (CA-MRSA). HA-MRSA has been an issue for many years and affects primarily those in hospitals and nursing homes, those with immune disorders, and those with recent antibiotic usage. CA-MRSA has been of concern only for two decades or so and does not need any of these requirements to infect individuals and thus even causes infections in otherwise healthy athletes.

MRSA can be the pathogen involved in many of the skin conditions described below. Treatment depends on the prevalence of MRSA in the community, the severity of infection, and the type of infection (MRSA is more likely to cause abscesses, although this is not a reliable identification measure). Oral antibiotics such as trimethoprim/sulfamethoxazole, clindamycin, doxycycline, or linezolid may be used to treat these infections, although more severe cases may need hospitalization with intravenous vancomycin. A full discussion of MRSA is found in the encyclopedia entry dedicated to that topic.

Folliculitis

Folliculitis is a superficial infection or irritation of the base of the hair follicles anywhere on the body. Athletes usually complain of mild to moderate tenderness or itchiness and have small pustules located at the base of the hair shafts, usually with a small amount of redness at the base of each pustule. Folliculitis in athletes can be broken down into three types: *Staphylococcus* L (either MRSA or methicillin-sensitive *Staphylococcus aureus* [MSSA]), *Pseudomonas folliculitis,* or *Pseudofolliculitis barbae*.

Staphylococcus folliculitis is the most common type of folliculitis and is usually found on areas of the skin under equipment pads, although it can occur anywhere on the body. Most of these infections are from MSSA strains of organisms, but MRSA can be an issue even in these small lesions. Treatment of these infections should include oral antibiotics and the use of antibacterial soaps to help prevent recurrence. The type of antibiotics given depends on the severity of the infection and the level of concern for MRSA. Treatment is usually for 7 to 10 days.

Pseudomonas folliculitis, also called "hot tub folliculitis," occurs most commonly as clustered lesions under swimming gear. As the name implies, poorly cleaned hot tubs or whirlpools are usually the cause of the infection. This is a self-limiting condition that typically lasts 5 to 7 days and usually does not respond to either topical or oral antibiotics. Appropriate cleaning of whirlpool facilities is essential to prevent infection and transmission.

Pseudofolliculitis barbae is not truly an infection but rather a reaction of the skin to ingrown hairs at sites of shaving. It has a presentation similar to that of true folliculitis but often does not have pustules that are as inflamed as in that condition. Treatment involves using fresh razors, manually releasing ingrown hairs with a sterile needle, or stopping shaving for several days to allow the hairs to grow out. Occasionally, there will be bacterial superinfection, in which case the condition should be treated as a true folliculitis.

Pitted Keratolysis

Also called "sweaty-sock syndrome," this is a condition presenting as sliminess and intense malodor of the feet, with a characteristic pitting of the skin of the foot almost exclusively at the pressure-bearing areas. It is commonly initially misdiagnosed as a fungal infection. Treatment of pitted keratolysis is to ensure a dry environment through the use of synthetic socks and an aluminum chloride antiperspirant (Drysol) and frequent changing of socks and footwear. Persistent lesions should be treated with topical antibiotics such as clindamycin or erythromycin. This is not usually considered a contagious condition, and players do not need to be held back from practice or play.

Erysipelas/Cellulitis

Cellulitis is differentiated from erysipelas by the fact that it involves the subcutaneous tissue, whereas erysipelas is essentially a superficial infection. Both involve redness, swelling, and pain of the involved tissue, and there may be red streaking found extending from the infection (called lymphangitis). In severe cases, there may be a fever, chills, and malaise.

These infections are usually caused by *Streptococcus* and *Staphylococcus* species in athletes, although many different types of bacteria may be responsible. Oral antibiotics are the treatment of choice, and strong consideration should be given to treating for MRSA in regions with a high prevalence or infections involving risky areas such as the groin, hands, and face.

Abscesses

Abscesses are closed pockets of infection within the skin and often underlying tissue. Friction is a high risk factor for developing these lesions, as are warm, moist environments. Unlike cellulitis and erysipelas, there is rarely any fever or chills unless the abscess is extensive or there is significant surrounding cellulitis. Abscesses are almost always caused by *Staphylococcus* species, and MRSA is of particular concern with these types of infections. Incision and drainage of the abscess under sterile conditions is highly recommended in most cases when feasible. Cultures should be obtained from the abscess contents. If the lesion is small, if the patient is otherwise healthy, and if he or she has a close follow-up with a medical provider, this alone may be sufficient treatment. Often, however, oral antibiotics are needed in addition to incision and drainage—particularly if surrounding cellulitis is present.

Erythrasma

Patients with this skin infection complain of discolored, reddish plaques between their toes or in their groin or armpits or between their buttocks. There is little to no pain, and often only mild itching or irritation. People with depressed immune systems, obesity, or excess sweating are more at risk of developing this infection. The diagnosis can be confirmed by shining a special fluorescent (Wood's) lamp on the patches, with a coral-red appearance indicating erythrasma.

The causative bacteria for these infections are *Corynebacterium* species, although there is a high association with concomitant fungal infections. Treatment consists of topical antibiotics, a combination of topical antibiotics and antifungals, or even oral antibiotics. This is a contagious condition, and so players should avoid contact, group showers, or shared footwear if any lesions are present.

Impetigo

One of the most contagious of bacterial skin infections affecting athletes, it is unfortunately also one of the most common. Impetigo can affect any area of skin but is most often found on the face. There are two types: bullous (bubble-forming) and nonbullous. Both types have a classic "honey-crusted" appearance to the lesions, although the lesions can also mimic cold sores, poison ivy, or even simple acne.

For simple cases, treatment can be simply the use of topical mupirocin (Bactroban), an antibiotic cleanser. This cannot penetrate any crust that is present, however, so any crust must be soaked off prior to application. Occasionally, oral antibiotics are needed to treat more severe infections. It is of utmost importance to quarantine any infected individual for at least 2 to 3 days after starting treatment to prevent spread among a team or region.

Mycobacterium Marinum Infections

Caused by bacteria related to those that cause tuberculosis, *Mycobacterium marinum* is a very rare skin condition that aquatic athletes can contract from infected freshwater or saltwater swimming areas. After several days to weeks after exposure, patients may present with nonhealing ulcerated lesions. Treatment is oral antibiotics for up to a year's duration.

Necrotizing fasciitis

Despite being extremely rare, this condition of "flesh-eating bacteria," as it is sometimes referred to in the popular press, is fairly well known. Athletes may present with a mild cellulitis, which can progress rapidly over hours to days to severe infection and death. Any such rapid progression or severe pain out of proportion to the appearance of an infection warrants immediate hospitalization for intravenous antibiotics and surgical debridement of the wound. Even with such precautions, as many as 1 in 4 patients die.

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See also Methicillin-Resistant *Staphylococcus Aureus* Infections; Skin Conditions in Wrestlers; Skin Disorders Affecting Sports Participation

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Skin Infections, Viral

Viral infections of the skin are commonly seen in athletes. Excessive sweating, tight clothing, and close skin-to-skin contact may contribute to the occurrence of infection. Because many of these diseases are potentially contagious to other athletes, a rapid diagnosis and initiation of treatment is important to prevent spread to teammates or opponents. Although most of the lesions resolve with no treatment, athletes often do require treatment in view of the high rate of transmission to other athletes if the condition is left untreated. Additionally, to reduce the spread of infection, the major sports organizations have set guidelines that require treatment of the lesion(s) and confirmation of resolution before allowing participation.

Verruca Vulgaris (Warts)

Warts most commonly affect the hands and feet and are caused by a strain of the human papilloma virus. The virus can enter through breaks in the skin, as in the case of an abrasion. The wart infects a superficial layer of the skin (the basal layer) and does not travel into the deep layers. The warts tend to grow slowly over 4 to 6 months. They can be spread either by direct contact with the virus or contact with an object that has come in contact with the virus (i.e., the mat in wrestling). If left alone, a majority of warts tend to resolve after about 2 years.

Treatment of warts focuses on direct destruction or surgical removal. The virus actively replicates at the base of the lesion, and so it may be necessary to remove the superficial layers before treatment is initiated to allow improved success of resolution.

Warts do not require that athletes be restricted from play. However, it will be necessary to have the lesions covered during competition. The National Collegiate Athletic Association (NCAA) rules that lesions should be "adequately covered."

Herpes Simplex Virus

The herpes simplex virus (HSV) is classified into two strains: Type 1 and Type 2. In general, HSV-1 is associated with lesions around the mouth. The lesions are very common in childhood. Occasionally, the lesions are asymptomatic, though they can be very painful and cause significant difficulty with eating. The initial infection often shows up from 1 to 3 weeks after contact with the virus. At the time of the first infection, the person may have a fever, headaches, and muscle aches and feel ill. After the initial infection, the virus lies dormant in the nerves of the face and has the potential to reactivate at a later point in life. Reactivation is often associated with physical or emotional stress, ultraviolet light, or fever (immune system stress). Usually, the person does not feel ill with a recurrent infection.

The infection appears as tiny blisters (called *vesicles*) with clear fluid and redness of the skin. Often, before the skin findings, an infected person may recall a feeling of tingling or burning in the location where the infection has settled. After the vesicle stage, the lesion may form a painful ulcer. Eventually, the lesions scab and dry up and self-resolve after 3 to 5 days. It is generally accepted that high doses of antiviral medications such as acyclovir or valacyclovir may help resolve the lesions. In some cases, a persistent use of the same medication in a lower dose can potentially help prevent recurrence of the infection.

The infection is so common in wrestlers that a particular name has been given to an HSV infection in that subset of athletes: *herpes gladiatorum*. In rugby players, HSV infection is known as scrum pox. It has been reported that 7.6% of college wrestlers and 2.6% of high school wrestlers are infected annually with the disease.

The NCAA has set guidelines for treatment and rules regarding return to play for athletes. Wrestlers who have HSV must be free of signs of infection (fever, muscle aches, feeling ill) for 72 hours and must not have any new lesions for 72 hours; all lesions must be dry, and the athletes should have been treated for at least 120 hours with oral antiviral medications before they can be released to practice or competition. For this reason, many athletes with the condition prefer to continue preventive therapy with antiviral agents throughout their season.

Varicella

Varicella is more commonly known as chicken pox and is part of the Herpesviridae family of viruses. As it is genetically similar to HSV-1 and HSV-2, it tends to produce lesions that are similar in appearance. The virus can grow rapidly and cause many lesions to show up in a short period of time. The entire body can be affected. Prior to the institution of immunization against varicella, it was a very common childhood infection. The lesions show up about 2 weeks after exposure to the virus. The skin rash proceeds in a predictable way—first as red flat spots, then raised spots, then small blisters, and finally a scab. Since the virus reproduces itself so rapidly, it is possible to see all stages of the lesions in an individual person at the same time. The condition is highly contagious and is probably spread most efficiently starting 2 days before the rash starts up until 7 days after the rash has started. Most children infected with varicella improve within a short period of time and have no permanent effects. Varicella is particularly dangerous to pregnant women in their first 5 months because of fetal damage. Adults tend to have a more serious illness at times, resulting in pneumonia or a brain infection.

Herpes Zoster (Shingles)

Once a person has had chicken pox, he or she tends to be protected from a second infection. However, the virus can lie dormant in the nerves of the body and may resurface in times of stress or in the elderly. This resurgence is known as herpes zoster or, more commonly, *shingles*. Shingles returns in a single nerve root and follows the course of the nerve. In many instances, this produces a red rash with small blisters in a line. Often this is seen across the neck, chest, or abdomen. A more serious recurrence can occur in the nerves of the face. With facial involvement, there can be paralysis of the muscles of the face that is usually temporary but can result in permanent deformity. Recently, an immunization against shingles has become available, and it could decrease this risk of recurrence.

Molluscum Contagiosum

Molluscum contagiosum is caused by a virus in the Poxviridae family. It appears as a painless bumpy rash with multiple small lesions. After contact with the virus, it may take from 1 to 6 months for the lesions to develop. The bumps are often of a pearly color and have a center that appears pressed in on itself. Most of the time, there are no symptoms associated with the rash. The infection is particularly common in children and tends to occur on their trunk, thighs, or upper arms. Children tend to pass the virus by direct contact with lesions. Adults can manifest the disease in their genital area, and the condition is often considered sexually transmitted. Most often the lesions regress in about 6 to 9 months. If the lesions are single, they can resolve in as short a period as 2 months. If treatments are recommended, they are focused on directly destroying the lesions by freezing them, chemically destroying them, or cutting them off. There are topical creams that can help resolve the lesions as well, but they tend to take about 1 month to clear the lesions.

The NCAA requires that lesions be removed in some manner before clearance for competition. Localized or solitary lesions can be covered with a dressing and taped. After removal, it is recommended that the athlete be removed from competition for 24 hours.

Allyson S. Howe

See also Skin Conditions in Wrestlers; Skin Disorders Affecting Sports Participation

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Skin Infestations, Parasitic

Parasitic skin infestations are infections of the skin caused by small organisms that require human hosts for a portion of their life cycle. These skin infections, including lice and scabies, rarely affect athletes when compared with viral or bacterial infections. Though these infestations are rare, any of them may affect an athlete's ability to participate in practice or competition. Symptoms include intense itching and the development of a rash or bite marks. Diagnosis is based on a clinical exam. The most common treatment for these conditions is topical medications. Scabies and lice are transmitted from person to person, meaning that actively infected athletes cannot be allowed to participate until treatment is complete.

Anatomy

The skin is the largest organ of the body. It covers an area of approximately 2 square yards (yd^2; 1 yd^2 = 0.84 square meters [m^2]). The skin ranges in thickness from 0.5 millimeters (mm) on the eyelid to more than 4 mm on the palms of the hands and soles of the feet. Up to 15% of a person's body weight is made up by the skin.

The skin has several major functions. It plays a major role in regulating the body temperature with a vast network of small blood vessels below the skin surface. The skin helps protect the body from damage, dehydration, and systemic infections. This protection is obtained by having a relatively impervious external layer of skin called the epidermis. Supporting the epidermis is an internal layer called the dermis. The dermis forms the support structure for the external layer.

Organisms that cause parasitic skin infestations have adaptations including special claws and suckers that can aid attachment to the epidermis. Lice exert their clinical effects on the skin surface, whereas scabies organisms burrow into the epidermis itself.

Lice

Causes

Lice are parasitic insects about 2 mm in length that survive by feeding on human blood. Lice infestations are caused by one of three different organisms, named for the human anatomic site that is affected. Pediculosis capitis refers to head lice, pediculosis corporis refers to body lice, and pediculosis pubis refers to genital lice. Transmission of the infection requires close skin-to-skin contact with another infected person. Rarely, the infection can be transmitted from clothing or equipment that was recently used by an infected person. Close skin contact can occur during athletic participation. Lice infestations are classically reported in sports such as wrestling, where there are prolonged periods of skin-to-skin contact. However, lice remain a rare cause of skin problems in the athlete. One-tenth percent of skin infections in college wrestlers are due to lice.

Symptoms

The bites of the lice lead to complaints of itching up to 10 days after exposure. The itching can be severe and is due to a local allergic reaction to the bite. Other symptoms can include a tickling sensation or a sensation of movement on the affected area. Sores can develop from repeated scratching.

Diagnosis

Diagnosis is made by observing the area of concern. The body part affected is examined for live lice or lice eggs, called "nits." Nits are small, white nodules attached at the base of a hair shaft. Nits can be mistaken for dandruff, hair spray droplets, or dirt particles. Use of a fine-toothed comb can facilitate visualization of an affected area. If live lice are seen, then the diagnosis of lice infestation is confirmed.

Treatment

Treatment of an affected athlete involves the use of topical medications to eradicate the infestation or make the skin inhospitable for the lice. Commonly used topical medications include permethrin 5% cream, pyrethrin cream, and lindane shampoo. There are multiple forms of the topical treatments, and each form has individual instructions for application. Some treatments require a doctor's prescription, while others are available over the counter in the pharmacy. Topical medications can typically be repeated 1 week after the initial treatment.

All clothing, hats, sporting equipment, and bedclothes used for 5 days prior to use of the topical medication require special handling. All items should be cleaned in a washing machine set to the hot cycle and dried at a high temperature. Any item that cannot be cleaned in this fashion should be placed in an airtight container for 3 to 5 days. These measures are designed to diminish the risk for reinfestation by an athlete's personal items.

Prevention

Preventing the spread of lice from one athlete to another can be promoted by employing several simple measures. Any athlete who has an active lice infestation should not practice or compete in any sport that requires skin-to-skin contact with other participants. Athletes need to have infestations fully treated before returning to play. The National Collegiate Athletic Association (NCAA) has special rules for wrestlers with skin infections. Collegiate wrestlers with lice are required to be fully treated before they are allowed to compete. At the time of a precompetition skin check, a physician or certified athletic trainer may disqualify a wrestler if there is evidence of active lice infestation.

Scabies

Causes

Scabies is a parasitic infestation caused by small parasitic organisms called *Sarcoptes scabiei* mites. The mite burrows into the epidermal layer of the skin. As the mite burrows into the skin, it deposits its eggs and fecal matter. The fecal matter of the mite is also called *scybala*. Transmission of the infestation is most often through close skin-to-skin contact with another infected person. Rarely, the infection can be transmitted from clothing or equipment that was recently used by an infected person. Scabies infestations are classically reported in wrestling, where there are prolonged periods of skin-to-skin contact during matches or practice. However, scabies remain a rare cause of skin problems in the athlete when compared with bacterial, viral, and fungal infections. Only 0.5% of skin infections in college wrestlers are due to scabies.

Symptoms

Athletes present with complaints of severe itching, especially at night. The affected athlete develops characteristic skin lesions within several weeks of exposure. These skin lesions can occur in the webbing of the fingers or on the hands, arms, legs, trunk, or groin. The lesions are classically thin, linear, red, slightly raised plaques but can also be diffusely spread red bumps or papules. In athletes who have had prior episodes of scabies, the symptoms can appear within a few days of reexposure. This can happen due to the host's immune system being reactivated quickly to the infestation.

Diagnosis

Diagnosis is made by carefully examining the lesions for characteristics of scabies as described earlier. A black speck that can just be seen by the naked eye at the end of a linear lesion represents the burrowing mite.

To confirm the diagnosis, a scabies preparation is performed. This preparation is done by scraping the linear plaques three or four times each with a scalpel blade in the direction of the visible black speck. The scrapings are then placed in a drop of mineral oil on a microscope slide. The slide is then examined with a microscope on a low-magnification setting. The presence of mites, eggs, or scybala is considered a positive result.

Treatment

Treatment of an affected athlete involves the use of topical or oral medications to eradicate the scabies infestation. A commonly used topical medication is permethrin 5% cream, applied to every surface of the body. The cream is left in place overnight and washed off in the morning. The topical medication therapy is typically repeated 1 week after the initial treatment. An alternative treatment is an oral medication called ivermectin. A single dose is given and then repeated 7 to 14 days later. The severe itching typically resolves within 1 or 2 days following the first treatment. However, a topical corticosteroid cream can be applied for cases of persistent severe itching.

All clothing, hats, sporting equipment, and bedclothes used for 5 days prior to the use of the topical medication require special handling. All items should be cleaned in a washing machine set to the hot cycle and dried at a hot temperature. Any item that cannot be cleaned in this fashion should be placed in an airtight container for 3 to 5 days. These measures are designed to diminish the risk for reinfestation by an athlete's personal items.

Prevention

Preventing the spread of scabies from one athlete to another athlete can be promoted by employing several simple measures. Any athlete who has an active scabies infestation should not practice or compete in any sport that requires skin-to-skin contact with other participants. Athletes need to have infestations fully treated before returning to play. The NCAA has special rules for wrestlers with skin infections. Collegiate wrestlers with scabies are required to be fully treated and have a negative scabies preparation before they are allowed to compete. At the time of a precompetition skin check, a physician or certified athletic trainer may disqualify a wrestler if there is evidence of active scabies infestation.

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See also Fungal Skin Infections and Parasitic Infestations; Skin Conditions in Wrestlers; Skin Disorders Affecting Sports Participation; Skin Infections, Bacterial; Skin Infections, Viral

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Skull Fracture

Sports and recreation–related head injuries, such as concussions, are relatively common. Fortunately, skull fractures occur very infrequently from athletic participation. With improvements in head gear and protective equipment, it has become rare that enough force is imparted to the skull to result in a fracture during athletic events. When a skull fracture does occur, however, it is important that it be promptly recognized and treated. Skull fractures typically result in injury to the brain, which may require emergent treatment.

Anatomy

The skull consists of a total of 27 bones that constitute two main regions. The first region is the bony covering around the brain (cranium), and the second region is formed by the bones constituting the face (Figure 1). The facial bones consist of the upper portion, which houses and protects the eyes and nose, and the lower portion, which helps form the jaws. This entry focuses on fractures to the first region of the skull, the cranium, which covers the brain.

During growth, the bones of the skull are connected by growth plates, which are also known as "sutures," that eventually fuse together. The bones are named based on their location. As shown in Figure 1, the bones covering the brain include the frontal bones, at the front of the skull; the sphenoid and temporal bones, at the side; the parietal bones, on the top; and the occipital bones, at the back of the skull. The major bones of the face include the nasal bone, forming the nose; the maxilla and the zygomatic bone, forming the upper jaw; and the mandible, forming the lower jaw. The mandible is technically not considered a part of the skull but rather a separate bone that connects to the skull via the temporomandibular joint or TMJ.

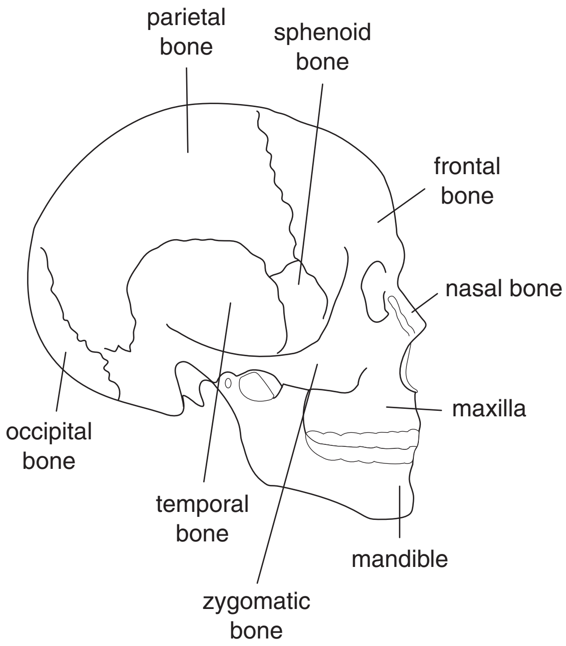

Figure 1 Some of the Major Bones Constituting the Face and Skull

Causes

A skull fracture is simply a break in a skull bone. The majority of skull fractures are not related to sports but result from motor vehicle accidents, falls, or violence. Skull fractures are grouped into four main types: linear, depressed, diastatic, and basilar. Linear skull fractures are the most common, accounting for about 70% of all skull fractures and virtually all fractures resulting from sports activities. With a linear fracture, there is a break in the bone, but the break does not result in any movement of the bone. With a depressed skull fracture, the area of the skull that is broken is pushed inward or appears sunken. This type of fracture has a higher risk of injury to the underlying brain. Diastatic skull fractures are fractures that occur along the growth plates or sutures of the skull. These fractures tend to occur in newborns and infants and are not typically seen after sporting activities. Basilar skull fractures are fractures that occur at the base of the skull or the portion underneath the brain. This type of fracture can occur even with helmet use in high-energy automobile racing accidents.

In sporting activities, fractures to the facial bones occur much more commonly than do fractures to the cranial bones. Improvements in head-and-face protection in sports such as football and hockey have led to a substantial decline in the number of cranial and facial fractures. Even in sports where very high impacts may be imparted to the head, resulting in injury to the brain, such as automobile racing, modern helmets have made the incidence of skull fractures quite low. Sports in which no protection is worn, such as soccer or rugby, actually account for a significant number of facial fractures and occasionally fractures to the cranium. A fracture can be caused by direct contact against another athlete, such as in a head-to-head contact in soccer. Fractures can also result from contact between the head and a piece of athletic equipment, such as the goalpost in soccer, or less commonly from contact against the ground. Fractures at the base of the skull (basilar fracture) can result from high-energy automobile racing accidents due to sudden compression forces imparted to that portion of the skull.

Symptoms

The symptoms resulting from a skull fracture depend on the type of fracture sustained. Athletes who have suffered a depressed skull fracture may be rendered unconscious due to underlying brain injury. With a linear skull fracture, the athlete may not lose consciousness but often will display symptoms consistent with a concussion, such as headache, confusion, and lethargy. Postconcussion symptoms can last for days to weeks and are listed below. Athletes who have suffered a linear skull fracture have pain and tenderness overlying the area of the fracture.

Diagnosis

The diagnosis of a skull fracture begins with a history and physical exam. The history usually reveals a high-energy mechanism, especially if the athlete wears protective headgear, as in auto racing. In some cases the headgear may not have been fit or functioned properly, as with a baseball player hit on the head by a pitch. In rare cases, the athlete may not have worn headgear at all, such as a soccer goalie who contacts the goal post with his

Postconcussion Signs/Symptoms

"Bell rung"	Nausea
Depression	Nervousness
"Dinged"	Numbness/tingling
Dizziness	Poor balance/coordination
Excessive sleeping	Poor concentration, easily distracted
Fatigue	Ringing in the ears
Feeling "in a fog"	Sadness
Feeling "slowed down"	"Seeing stars"
Headache	Sensitivity to light
Inappropriate emotions or personality changes	Sensitivity to noise
Loss of consciousness	Sleep disturbance
Loss of orientation	Vacant stare/glassy eyed
Memory problems	Vomiting

head, resulting in a fracture. Most athletes who have sustained a skull fracture are rendered unconscious from the initial impact to the skull and underlying brain. Although the neurologic injury and other associated injuries take precedence over the skull fracture in initial treatment, diagnosis of the skull fracture is important to minimize potential late complications. Depressed and open skull fractures should be apparent in a physical exam; however, linear skull fractures may not be obvious.

A diagnosis of linear skull fractures and fractures at the base of the skull is typically made on radiographic imaging. Plain radiographs have essentially been supplanted by the computed tomography (CT) scan in the imaging of the skull and brain. The CT scan is much more sensitive in detecting subtle fractures of the skull, especially those at the base of the skull. Unlike plain radiographs, a CT scan also images the brain and will detect bleeding in or around the brain. A magnetic resonance imaging (MRI) scan will also show skull fractures but is best for evaluating the brain for bleeding, contusion, or a shearing-type injury.

Treatment

Nonsurgical Treatment

The initial treatment for an athlete with a skull fracture focuses on the ABCs (airway, breathing, and circulation) of advanced trauma life support. The athlete's cervical spine should be immobilized with a rigid collar until spine injury can be ruled out. The athlete should be transported to a medical center that provides neurosurgical services. In the rare event of an open skull fracture, the wound should be covered with sterile gauze and intravenous antibiotics administered.

Linear skull fractures are typically treated nonoperatively. Ice can be applied to the area of contact to minimize swelling. A computed axial tomography (CAT) scan should be obtained to evaluate the underlying brain tissue for injury or bleeding. The CAT scan also accurately shows the extent of the fracture. Patients should be monitored for at least 24 hours to assess for deterioration in neurologic functioning. Narcotic pain medication should be avoided or given in limited quantities to minimize difficulty in diagnosing changes in neurologic status.

Surgery

Depressed skull fractures require surgery to eliminate pressure on the underlying brain tissue. Open skull fractures also require surgery to wash out the wound, elevate the depressed portion of the skull, and close the wound. These injuries represent surgical emergencies to minimize further brain injury and decrease the risk of infection. Since depressed and open skull fractures tend to result from very high-energy injuries, surgery may also require evacuation of underlying hematoma.

Rehabilitation

Nonsurgical Rehabilitation

Linear skull fractures heal without any surgical intervention. The fractures typically unite by 6 to 8 weeks after the injury. The type and extent of rehabilitation depend mostly on the degree of associated brain injury. Athletes who have sustained a concussion can return to athletic activity once the fracture has healed and all postconcussive symptoms have resolved both at rest and during activity.

After Surgery

Return to athletic competition after a skull fracture that requires surgery is controversial. Whether an athlete attempts to return depends on multiple factors, including the extent of brain injury and the nature of the sport that resulted in the injury. It is not the fracture, which typically heals without incident, but the extent of damage to the brain that is the most important factor in the athlete's long-term prognosis. To even consider returning to athletic competition, the athlete must have a complete neurologic recovery and not be at increased risk for repeat brain injury. Given that this is such a rare occurrence, there are no studies to help guide physicians in managing a patient.

Robert Victor Cantu and Robert C. Cantu

See also Concussion; Emergency Medicine and Sports; Fieldside Assessment and Triage; Head Injuries

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Sleep and Exercise

Exercise has been proposed as offering a safe and healthy means of alleviating insomnia and other sleep disorders. This entry discusses the impact of sleep disorders, reviews the surveys and epidemiologic evidence supporting the benefits of exercise, and discusses the potential mechanisms by which exercise can promote healthy sleep patterns.

In industrialized countries, the annual global incidence of insomnia is approximately 30%. The prevalence of sleep problems increases with age, such that more than 50% of adults over age 60 have some sleep-related complaint.

Insomnia has been associated with physical and mental illness, impaired quality of life, and increased risk of automobile accidents. Moreover, in the United States, the costs associated with the resulting worker absenteeism, declines in work productivity, and increases in health care utilization have been estimated at approximately $14 billion.

Individuals' reactions to disturbed sleep and self-help strategies can often exacerbate and perpetuate insomnia. For example, excessive worry about insomnia and attempts to compensate by spending extra time in bed can lead to a vicious cycle dynamic of further sleep problems.

Many physicians who are untrained in dealing with sleep problems are most inclined to treat patients with sleeping pills. However, sleeping pill use has been associated with daytime sedation, "sleep driving," and impaired cognition; and chronic nightly use has been associated with a mortality risk comparable with that associated with smoking a pack of cigarettes per day.

Hence, there has been an increased interest in cognitive/behavioral treatments for insomnia. There is compelling scientific evidence that these treatments are superior to sleeping pills for chronic treatment of insomnia. However, the treatments are costly and time-consuming, and there are not enough clinicians who are trained to administer these treatments. Thus, other self-administered treatments would be helpful.

Exercise is almost invariably included in both expert and lay recommendations for improving sleep. The expectancy that exercise promotes sleep is centuries old; moreover, the notion that exercise promotes sleep has been consistent with historical theories about the function of sleep. For example, theories that sleep serves an energy conservation or body restitution function naturally led to hypotheses that energy utilization and body tissue breakdown associated with exercise could elicit unique needs for sleep. These theories influenced much of the earlier research on exercise and sleep. However, they have been largely discredited on the basis of evidence, for example, supporting the idea that sleep is associated with only a minimal reduction in oxygen consumption and no particular increase in protein synthesis or replenishment of adenosine triphosphate (ATP) stores.

Undoubtedly, some of the interest in this topic stems from anticipation that exercise could be a very attractive alternative or adjuvant treatment for insomnia. Exercise has profound health benefits and would be a comparatively safe, inexpensive, and simple means of improving sleep. Besides affecting insomnia and sleep quality, there are also theoretical and empirical rationales for expecting that exercise could be a useful alternative or adjuvant treatment for several other sleep disorders, such as sleep apnea, restless legs syndrome, and circadian rhythm sleep disorders.

Insomnia/Sleep Quality

Survey Results

Surveys have consistently shown that exercise promotes sleep. For example, in a National Sleep Foundation poll, people who reported exercising regularly also reported fewer complaints of difficulty falling asleep, difficulty staying asleep, waking up unrefreshed, or daytime sleepiness compared with people who reported exercising less frequently than once per week, and these associations showed a dose-response pattern.

In other population surveys, people have consistently reported that exercise helps them sleep better. For example, Urponen and colleagues studied a random sample (n = 1,090) of people in Tampere, Finland, who were prompted thus: "Please state, in order of importance, three practices, habits, or actions which you have observed to best promote your falling asleep or your quality of sleep." The respondents (men, 33%; women, 30%) reported that exercise was the most important behavior, more important than reading or listening to music (men, 15%; women, 23%), taking a sauna/shower (men, 9%; women, 9%), and psychological factors (men, 8%; women, 9%).

Although these survey results are provocative, it is plausible that they might overestimate the benefits of exercise for sleep. Physically active people tend to have better physical and mental health, which are conducive to sleep, and they tend to engage in other healthy behaviors that are conducive to sleep, such as avoidance of smoking and excessive alcohol consumption.

Moreover, people are not always accurate in their assumptions about sleep. For example, although the "nightcap" is commonly used to promote sleep, it is well established that alcohol actually impairs sleep. Likewise, people might assume that exercise promotes their sleep on the basis of a common, but incorrect, assumption that physical fatigue is synonymous with sleepiness.

Interestingly, survey data have unanimously failed to support the common assumption that late-evening exercise will disrupt sleep. For example, assessing a random sample that includes people who reported exercising after 8 p.m. (n = 320), Vuori and colleagues in Finland found that the majority of these people reported that after exercise, they fell asleep more quickly (65%), had deeper sleep (62%), and woke up feeling better (60%).

Epidemiologic Results

Epidemiologic studies could theoretically provide stronger evidence that exercise promotes sleep because they can statistically control for some of the potential confounds listed above. Epidemiologic studies have consistently found that self-reported exercise is significantly independently associated with less insomnia and other sleep complaints. These associations have been observed across all age-groups and various ethnicities around the world. The association of exercise with better sleep has generally been modest compared with other predictors (e.g., depression and stress/anxiety), but the association has been more consistently established than for perhaps any other behavior. Moreover, if exercise indirectly promotes sleep via its antidepressant/anxiolytic effects, then these studies might underestimate the effect of exercise.

Nonetheless, there are a number of limitations of the epidemiologic studies linking exercise with better sleep. First, with few exceptions, these studies have relied on self-reported measures of exercise and sleep. These measures have often had unknown reliability and validity. Second, as discussed above, causality cannot be definitively inferred from epidemiologic associations. The epidemiologic associations could be explained by external factors, such as incidental outdoor light exposure, which has been associated with better sleep. Moreover, fatigue is a barrier to exercise, so people who sleep better might be more inclined to exercise. Third, the studies often have not adequately measured or controlled for health status and other behaviors that can affect sleep.

Experimental Studies

Acute Exercise

Approximately 50 experimental studies have examined the effects of acute exercise on sleep in comparison with sedentary control treatments. These studies have focused predominantly on laboratory polysomnographic measures. Our meta-analysis of this literature summarized the effect and explored potential moderating factors. The meta-analysis found that acute exercise elicited virtually no effect on how long it took subjects to fall asleep or how much they were awake during the night and that exercise elicited a statistically significant but modest increase in total sleep duration (median 10 minutes), a significant but small increase in slow-wave sleep (SWS) (1.6 minutes), a significant increase in rapid-eye-movement (REM) latency (11.6 minutes), and a significant decrease in total REM duration (6 minutes).

The effect of acute exercise on sleep duration was significantly moderate by exercise duration, with negligible effects for exercise durations of less than 1 hour (2 minutes) and progressively greater effects following exercise of 1 to 2 hours (11 minutes) and more than 2 hours (15 minutes). This finding raises some questions about the practical utility of exercise for promoting sleep since many people are unwilling to exercise for 1 hour. On the other hand, no moderating effects of fitness or exercise intensity were found, which is consistent with survey and experimental evidence that exercise promotes sleep across the population.

Also consistent with surveys, experimental evidence indicates that late-evening exercise does not impair sleep for most individuals. This lack of impairment has been found in sedentary individuals as well as physically active individuals and has been seen even following vigorous exercise of 1 to 3 hours' duration, ending only 30 minutes before bedtime.

In summary, experimental studies have found significant, but quite modest, beneficial effects of acute exercise on sleep. However, there have been a number of limitations of these studies that might explain the modest effects. First, the studies have often had small sample sizes. Second, the studies have typically been limited to one or two nights. Because sleep is sensitive to many factors, more assessment nights might be needed to delineate the effects of exercise. The most important limitation is that the studies have focused almost exclusively on good sleepers, who have little room for improvement. Indeed, it has been shown that acute exercise and sleeping pills have quite comparable effects in good sleepers. Whether exercise will also have an effect similar to sleeping pills in insomniacs is a question worthy of future research.

Chronic Exercise

Chronic exercise studies have also generally revealed only modest beneficial effects of exercise on sleep. However, most of these studies have also been limited to normal sleepers. Several recent studies have examined whether exercise training could improve sleep in older adults, who tend to have worse sleep compared with young adults. In general, the results do not suggest more beneficial effects of chronic exercise in older versus young adults. There is some limited evidence of greater benefits of chronic exercise in older adults with insomnia, as might be expected. However, this evidence is limited mostly to self-reported sleep, which could be confounded by expectancy effects and demand characteristics. Further research involving insomniacs and objective sleep measures is needed.

Obstructive Sleep Apnea

Obstructive sleep apnea (OSA) affects about 10% of the adult population and has been associated with cardiovascular disease, diabetes, and mortality. The primary treatment for OSA, continuous positive airway pressure (CPAP), has limited efficacy and is associated with dismal compliance. There is recent interest in the notion that exercise could help reduce OSA severity or at least offset some of its hazardous consequences.

Epidemiologic studies have consistently shown an association of exercise with reduced symptoms and diagnoses of OSA. For example, Peppard and Young of the University of Wisconsin-Madison found that the relative risk of polysomnographically determined sleep apnea (>5 events per hour) was 0.62, 0.39, and 0.31 in respondents (n = 1,104) who reported exercising 1 to 2 hours, 3 to 6 hours, and 7 hours or more, compared with 0 hours per week. Although weight loss is an obvious potential mechanism by which exercise could indirectly reduce apnea, the association of exercise with reduced apnea has persisted following control for body mass index and skin fold thickness.

Uncontrolled experimental studies have revealed that exercise training can reduce OSA severity, and these effects were not correlated with weight loss. A recent randomized controlled study found that exercise training significantly reduced central sleep apnea (a rarer type of apnea) in patients with chronic heart failure.

Restless Legs Syndrome

Restless legs syndrome (RLS) is associated with excruciating "creepy-crawly" sensations in the legs, which cause an irresistible urge to move the legs, primarily at night when one is trying to sleep. The presence and severity of RLS has been strongly linked to genetic factors, as well as iron and dopamine deficiencies. Anecdotally, people who suffer from RLS report that moderate daytime exercise can help prevent or reduce the severity of RLS symptoms at night. Moreover, exercise involving the legs is the best remedy for acute RLS symptoms. Epidemiologic research by Phillips and colleagues of the University of Kentucky has also indicated that exercise is associated with reduced RLS. Finally, randomized controlled research has shown that both acute and chronic exercise can reduce the symptoms of RLS. In one study by de Mello and colleagues in Sao Paulo, Brazil, the effects of exercise were comparable with those of L-dopa, one of the primary pharmacologic treatments for RLS.

Mechanisms by Which Exercise Could Promote Sleep

Anxiolytic Effect

Exercise could promote sleep via anxiety reduction. Clearly, anxiety disturbs sleep, and there are dozens of studies that indicate that acute exercise can reduce state anxiety and chronic exercise can reduce trait anxiety. The anxiolytic effect of acute exercise provides some rationale for expecting that the evening might be the best time to exercise since the anxiolytic effects are best established during the first few hours after exercise.

Antidepressant Effect

Since depression is also clearly linked with poor sleep, exercise could also promote sleep, indirectly, via its well-established antidepressant effects. Singh and colleagues at Harvard University conducted a 16-week exercise training study of depressed individuals and found that sleep-promoting effects were significantly correlated with antidepressant effects. Some evidence suggests that the efficacy of antidepressant drugs might be mediated partly by decreases in REM sleep and increases in REM latency, and so it is plausible that the antidepressant effects of chronic exercise might also be partly mediated by the REM changes that have been observed after acute exercise.

Thermogenic Hypothesis

One of the most widely accepted hypotheses in this area is that exercise could promote sleep via body-heating effects. This hypothesis is supported by evidence that the anterior hypothalamus/pre-optic area of the brain is associated with both sleep regulation and body cooling and that passive heating (e.g., in hot tubs) can promote sleep. Most compellingly, Horne and colleagues at Loughborough University in the United Kingdom have shown that experimental blunting of temperature elevation during exercise (via body cooling) can attenuate some of the beneficial effects of exercise on sleep. Chronic exercise could also potentially promote more rapid temperature downregulation at night, which has been linked with sleep onset.

Circadian Phase-Shifting Effect

Exercise could also have a positive effect on sleep via its influence on the circadian system. One of the hallmark features of primary insomnia is an erratic sleep-wake schedule. There is evidence that exercise can help stabilize the circadian system, which could, in turn, stabilize and improve sleep.

Moreover, there is compelling evidence that exercise can shift the circadian system, which could help correct circadian rhythm sleep disorders. Exercise and bright light have also been shown to have additive phase-shifting effects, both in animals and humans. Delayed sleep phase syndrome, which often prevents one from going to sleep before 2 a.m. or arising before 10 a.m., is particularly prevalent in adolescents and young adults. This condition can result in profound sleep deprivation, absenteeism and tardiness, and impaired academic and work performance. The circadian phase–advancing effects of morning exercise could help correct this problem. Conversely, the phase-delaying effects of evening exercise could help treat advanced sleep phase syndrome, which tends to cause one to go to bed before 9 p.m. and wake up before 4 a.m.

About 20% of the U.S. workforce are shift workers. Shift work is associated with chronic sleep problems as well as many other morbidities, including heart disease, cancer, mood disturbance, and gastrointestinal distress. In a randomized, controlled experiment involving a simulated "graveyard shift," we found that nighttime exercise facilitated circadian adjustment to the shift and resulted in a significant reduction in symptoms.

Conclusion

It is commonly assumed that exercise is one of the most important behaviors promoting sleep. Surveys and epidemiologic studies have supported this assumption. Experimental studies have shown more modest effects of acute and chronic exercise on sleep. However, these studies have been limited to good sleepers. More promising results have been found in studies of exercise in people with sleep problems. Further randomized controlled research of this type is needed. Moreover, there should be verification of the exciting evidence that exercise might be an effective treatment for sleep apnea, RLS, and circadian rhythm sleep disorders.

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Note: Preparation of this entry was supported by HL71560 and a VA (VISN-7) Career Development Award.

See also Circadian Rhythms and Exercise

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Sleep Loss, Effects on Athletic Performance

Sleep has always been thought of as a critical factor for optimal performance in athletics. Research has established that sleep is an active physiological state and not a passive process and is as complex as wakefulness. Critical cognitive, immunological, and metabolic processes occur during sleep, but its direct relationship to athletic performance is still unproven.

Both sleep and athletic performance are extremely individual activities and are influenced by many factors and variables, making research on this subject difficult to perform. However, scientific evidence is emerging that confirms a connection between sleep and athletic performance.

This entry describes the basic circadian rhythms and stages of sleep; the causes of sleep deprivation; sleep requirements; the effects of sleep deprivation through cognitive, immunological, and metabolic impairment; sleep quality; and recovery.

Circadian Rhythms

Circadian rhythms, or biological rhythms, are physiological parameters that fluctuate in specific ways over a 24-hour cycle. Sleep and wakefulness are among those rhythms. Circadian rhythms are genetically and environmentally determined in humans. Each athlete has a preferred sleep schedule that best suits his or her circadian phase. If a circadian preference and sleep schedule are not harmonized, or get out of phase, it will affect the amount and quality of sleep of the athlete.

Overview of Stages of Sleep

The American Academy of Sleep Medicine (AASM) uses a standardized method for describing sleep. This was revised in 2007. The modified stages of sleep and general outline include the following:

- Sleep is analyzed in 20- to 30-second epochs, with each epoch being assigned a single sleep stage.
- Sleep is subdivided into two general states: rapid eye movement (REM) sleep and non–rapid eye movement (NREM) sleep. NREM sleep is further subdivided into four stages.
    - *REM:* Electroencephalogram (EEG) findings show rapid, low voltage, similar to an active, awake EEG pattern. High-frequency beta waves occur with frequent bursts of REM. Most vivid dreaming occurs during this stage.
    - *NREM:* This accounts for up to 80% of total sleep time in human adults.
        - *Stage 1:* In this stage, the brain transitions from wakefulness to sleep or from alpha waves to theta waves. The muscle tone is lost, and the person loses awareness of the external environment. This stage lasts for only minutes, before the person moves on to the next stage.
        - *Stage 2:* EEG findings are characterized by higher "sleep or theta spindles" and "k-complexes," which are thought to be associated with arousal. This stage accounts for up to 55% of total sleep and lasts only a few minutes.
        - *Stages 3 and 4:* (the new AASM guidelines combine Stages 3 and 4). These are characterized by "deep sleep" or "slow-wave sleep." Delta waves are more pronounced. This is the last and deepest of the sleep stages before REM sleep. If a person is deprived of this stage of sleep, it rebounds once sleep is allowed again, suggesting that this stage is essential to the sleep process.

The true function of REM sleep is uncertain, although some data suggest an important role in memory consolidation. Some data indicate that NREM sleep has an association with the restorative functions of sleep, that is, restoration of alertness and energy. The data indicate that deep sleep is increased in athletes after significant physical effort.

Causes of Sleep Deprivation

Many circumstances can contribute to sleep disturbance and disruption of normal sleep cycles in an athlete. Some of these are work, academic and practice schedules; difference in time zones while traveling; pre-event anxiety or excitement causing early sleep arousal; early start of an event; diet; lifestyle choices; or jet lag.

Though many studies have produced mixed results or show methodological flaws in establishing whether optimal performance is influenced by transmeridian flights, one study showed that an appropriate choice of itinerary and lifestyle did indeed reduce the negative effects of jet lag in athletes.

Sleep Requirements

There is great interest in the ideal sleep requirement for an athlete to "rest and recuperate." Individuals respond differently to workout routines, and sleep deprivation and their sleep need vary.

In a 1994 National Institute of Mental Health study, participants with a "stabilized" sleep pattern averaged 8 hours and 15 minutes—a figure that is often interpreted as the amount of sleep that most adults require. Recent studies show that teenagers need as much, if not more, sleep as younger children (an average of 9.25 hours per night).

Though significant differences exist among individual athletes in their degree of vulnerability and responses to sleep deprivation, eventual negative effects have been shown to be cumulative. Sleep restriction practiced on a chronic basis induces performance deficits of the same order and magnitude as those observed during a large single event of total sleep deprivation. For example, if a person with a usual nightly sleep quota of 8 hours sleeps only 7 hours, there is a 1-hour sleep deficit that is carried over to the next day. A 7-hour sleep debt accrues after 7 days of losing 1 hour of sleep a night, nearly equal to a full night without sleep.

Effects of Sleep Deprivation

Though the direct effects of sleep deprivation on an athlete's performance are unproven, their relationship to the human body's metabolic processes, immunological function, and cognitive processing is more established and is related to a variety of adverse consequences.

Cognitive Impairment

Studies demonstrate a causal relationship among sleep, memory, and performance. Though not related to sports, major catastrophes such as In a 2008 study published in *Neurologic Clinics,* Three Mile Island accident, Chernobyl nuclear plant disaster, Exxon Valdez oil spill, and Space Shuttle Challenger disaster have been attributed to the poor judgment of sleep-deprived workers.

Dr. Charles Samuels cites previous research that has shown that sleep restriction (sleep deprivation) is linked to cognitive impairment with distinct interindividual variability. Cognitive performance (psychomotor vigilance) is directly affected by sleep deprivation. The impact of sleep disturbance on learning and neural plasticity (changes that occur in the brain as a result of experience) has also been established.

Sleep-deprived patients have reported decreased energy levels. They have difficulty with short-term memory, attention, alertness, speed, hand-eye coordination, and decision making—all of which are relevant to optimal athletic performance. These symptoms often disappear when normal sleep is restored.

Immunological Impairment

Chronic reduction in sleep can lead to immunosuppression. The integrity of normal immunological functions is negatively affected by sleep restriction. Studies have shown that partial or total sleep deprivation resulted in increased plasma levels of immune system "messengers" (tumor necrosis factor alpha [TNF-α] and interleukin 6 [IL-6]), which are involved in immune regulation. These "messengers" serve to connect the nervous, endocrine, and immune systems.

According to Samuels, there is a critical relationship between physiological recovery during sleep and an athlete's ability to train at maximum capacity with optimal results. The phenomenon of overtraining syndrome or chronic training fatigue is believed to result chiefly from immunological, neuroendocrinological, and musculoskeletal factors. The athlete's total sleep need and ongoing sleep debt are key factors in postexercise recovery, performance, and susceptibility to overtraining syndrome.

Metabolic Impairment

In a 1999 article published in *Lancet,* K. Spiegel and colleagues showed that sleep-deprived participants metabolized glucose less efficiently, leading to a reduced ability to manage glucose (similar to what is found in the elderly), decreased activity of human growth hormone, and elevated serum cortisol. Theoretically, elevated cortisol levels may interfere with tissue repair and growth and may lead to overtraining and injury.

Other detrimental changes in normal body metabolism due to sleep deprivation have been published, including delay in the healing of wounds, which has been shown in a study of rats with burn wounds. One night of sleep deprivation shows abnormal findings in electrocardiogram (EKG) testing (significant increase in QT max, QTd, cQTd, and P waves) in healthy young adults. These EKG changes can contribute to the development of arrhythmias. The effects of sleep deprivation on P waves may contribute to atrial fibrillation.

Sleep Quality

It is not enough to have an adequate quantity of sleep. An athlete may sleep for 8 hours or more and still be sleepy, secondary to disturbances in sleep quality. Sleep quality is another factor affecting performance in athletes. The full "restorative" benefit of sleep may not be received if sleep is fragmented by recurrent arousal without full awakening or light sleep with recurrent awakening.

Athletes experiencing "nonrestorative sleep" may become more tired from training, which affects performance and recovery. Optimal sleep quality may facilitate optimal athletic performance.

Recovery

When overcoming the effects of sleep deficit, any possible sleep "disturbance" should be minimized to allow normal and full sleep cycles to produce a full restorative benefit.

A positive or mitigating effect of "recovery sleep," that is, strategic napping, has been established as well in sleep deprivation studies, and it helps improve alertness and aspects of physical performance.

A Stanford University study showed that "extra" or extended sleep may boost athletic performance. Subjective reports of improved sprint times, increased free throw percentage, higher energy, and improved mood were obtained in six members of the men's basketball team who were instructed to "get as much sleep as possible" over a 2-week period. Studies with a larger sample may provide more meaningful results.

Conclusion

Determining an athlete's sleep patterns and ideal sleep needs and optimizing opportunities to allow optimal sleep quality so that the full restorative benefit of sleep can be achieved should be the current goal of coaches and athletes.

Coaches and athletes can make reasonable decisions to reduce the negative impact of sleep loss and encourage sleep quality as well as quantity. Traveling athletes can minimize the negative effects of readaptation when traveling over time zones by strategically planning their itinerary and lifestyle choices. Above all, further research must be conducted on the effect of sleep on athletic performance.

Mitchell Pratte

See also Circadian Rhythms and Exercise; Sleep and Exercise

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Slipped Capital Femoral Epiphysis

Slipped capital femoral epiphysis (SCFE) is an orthopedic emergency. It must always be considered in an adolescent with hip pain. Any young patient presenting with knee pain should always have his or her hips examined for SCFE. Treatment suggested is primarily surgery to prevent further damage and destruction to the femur (thighbone).

Anatomy

SCFE occurs at the femur in the hip joint. Specifically, the femoral head is the area that is part of the hip joint; the pelvic portion is called the acetabulum. The femoral head has a growth plate or epiphyseal plate, which is wider and weaker than normal bone. The slip is actually a Salter-Harris fracture (the classification for fractures involving the growth plate) that occurs in that growing and weakened area of bone.

Causes

SCFE happens in about 1 to 10 per 100,000 people. It is nearly 2.5 times more common in males than in females. It usually occurs in boys between 10 and 16 years of age and girls between 12 and 14 years. African Americans have a higher incidence of SCFE. About 25% of SCFEs are bilateral or affect both hips.

Obesity is a risk factor, because it increases the shear forces on the growth plate in the femoral head. Genetics may play a role as well. Of the patients with SCFE, 5% to 7% have another family member with the injury.

Metabolic and endocrine disorders also increase the risk of SCFE. Any patient with SCFE who is less than 10 years of age should have a metabolic and endocrine evaluation. These disorders include hypothyroidism, hypopituitary disorders, growth hormone deficiency, hypogonadal syndromes, and renal osteodystrophy. Bilateral SCFE is more common in young patients.

Clinical Evaluation

SCFE should be diagnosed and treated as quickly as possible to decrease the risk of long-term complications.

History

Most patients will complain of hip pain with decreased range of motion and difficulty weight bearing. Some will complain of knee pain (the pain radiates down the obturator nerve, which can confuse the examiner). The duration of symptoms should be obtained. If it is longer than 3 weeks, it is deemed chronic, whereas if it is less than 3 weeks, it is considered acute SCFE. Occasionally, patients will present with hip pain that has lasted longer than 3 weeks along with an acute worsening of pain or limp. This is termed *acute on chronic SCFE.*

It is important to inquire about family history and about symptoms consistent with the metabolic and endocrine disorders mentioned above.

Physical Exam

Some, but not all, patients may be obese. They classically hold the affected leg in external rotation or the foot pointed away from the body. This outward rotation may worsen with forward bending (flexion) of the hip. Testing of hip range of motion will be painful. It should be determined whether they can weight bear. It is always important to examine the opposite hip. Finally, the physical exam should also look for clues to endocrine and metabolic disorders.

Diagnostic Imaging

X-rays should be obtained. It is necessary to obtain X-rays of the opposite hip not only to rule out bilateral disease but also to use it for a comparison with the injured hip. Radiographs should include two views, usually a front-to-back film (AP or anteroposterior) and a "frog leg" view. However, if the patient is known to have SCFE, the frog leg view may potentially worsen the slippage, so a cross-table lateral view should be obtained.

The X-rays should be assessed to classify the amount of slippage and to see if there is other damage to the femoral head.

Blood testing for endocrine and metabolic disorders is necessary only in patients younger than 10 years or patients with other signs or symptoms of the disorders. Magnetic resonance imaging (MRI) and computed tomography (CT) are not helpful with diagnosis.

Postsurgical radiograph of a patient with an SCFE

Source: Kevin D. Walter, M.D., Children's Hospital of Wisconsin.

Patient's right side shows the normal femoral head; the left side shows SCFE.

Source: Kevin D. Walter, M.D., Children's Hospital of Wisconsin.

Classification

There are three ways to classify SCFE. The most important is stable or unstable. A stable SCFE means that the patient is able to weight bear. An unstable patient cannot put any weight on the affected leg because of the pain. An unstable SCFE means that the patient is likely to get progressively worse.

The next classification is based on the duration of symptoms. This includes chronic, which is greater than 3 weeks, and acute, which is less than 3 weeks of symptoms. The term *acute on chronic* refers to greater than 3 weeks' duration of symptoms but with a recent worsening of symptoms.

Finally, the amount of slippage can be determined by looking at the X-rays. Type I is less than 33% displacement. Type II is 33% to 50% displacement. Type III is more than 50% displacement. The larger the degree of displacement, the more likely the patient will have complications.

Treatment

SCFE is an orthopedic emergency. The patient should be non–weight bearing at all times. An orthopedic surgeon should be immediately contacted to evaluate the patient.

The most common treatment is surgery or internal fixation. The surgeon will use screws to fix the femoral head to the femur. This screw goes through the growth plate. The screw will provide stabilization, which can reduce the risk of further slipping. The screw also can cause the growth plate to close earlier than usual, which increases stability.

This procedure is done shortly after diagnosis to reduce the risk of avascular necrosis (AVN) or bone death of the femoral head. The femoral head is supplied by a single blood vessel that runs through the hip joint. As SCFE worsens, there is a chance that the blood flow will be disrupted, which causes AVN. The cartilage on the joint surface of the femur (articular cartilage) can be damaged as well. This is called chondrolysis. These two complications can lead to disability, pain, and early arthritis.

Since the blood vessel that supplies the femoral head is very sensitive, the slipped portion is rarely repositioned in the anatomically correct position. It is usually just fixated in its slipped position, due to fears that repositioning may damage the blood vessel.

Prophylactic bilateral fixation is controversial. Some surgeons feel that the risk of the opposite hip becoming affected is an indication for surgery on both hips. Other surgeons feel that it is not necessary to operate both sides unless the patient is younger or has an endocrine disorder, because both these issues have a higher risk of bilateral involvement.

Casting and other surgical procedures have been done in the past, but they have a high rate of complication, and thus have fallen out of favor.

After Surgery

The surgeon will discuss after-surgery care. Usually, patients are non–weight bearing or partial weight bearing on crutches for about 6 to 8 weeks after the surgery. Rehabilitation exercises after surgery can minimize weakness and improve strength.

X-ray follow-up until the growth plates close is recommended. During this time, leg lengths should be observed as well. Since the goal of surgery is to prematurely close the growth plate in the proximal femur (near the hip), the affected leg may be shorter than the unaffected leg.

There is some controversy about return to sports and contact sports. Some surgeons allow return after the growth plate has closed, some do not allow a return to contact sports, while others may allow return before growth plate closure. This is best discussed on a case-by-case basis with the surgeon.

Of course, if there are concerns for endocrine or metabolic disease, it may be worthwhile to follow up with a primary care provider or an endocrinologist for further evaluation.

Most patients who have a smaller percentage of slippage do quite well with early diagnosis and treatment. However, patients who are diagnosed late, as well as patients with severe slippage, may have more complications. The complications of AVN and chondrolysis may lead to chronic pain and early onset arthritis, both of which can lead to significant disabilities.

Kevin D. Walter

See also Hip, Pelvis, and Groin Injuries; Hip, Pelvis, and Groin Injuries, Surgery for; Hip Fracture; Musculoskeletal Tests, Hip; Orthopedist in Sports Medicine, Role of; Referred Pain

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Slipped Disk

Spinal pain is a common reason for preventing athletes from participation in sports. The spine is composed of the cervical (neck), thoracic (upper back), and lumbar (low back) vertebrae. Approximately 20% of athletes will experience back pain during a 1-year period. Neck pain will occur in about 10% of athletes overall during this time period. Of course, this will vary from sport to sport. The cyclist will have a much higher prevalence of neck pain, while the gymnast will complain more of low back pain.

The sources of spinal pain are multiple and include the surrounding muscles, the ligaments, the facet joints, and the intervertebral disk. The disk accounts for up to 25% of spinal pain. However, there are a number of pathologic processes that are associated with the disk. It may degenerate with loss of fluid and height. Or the disk may rupture, which is called a *herniated disk* or, in lay terms, a "slipped disk." To prevent and to properly rehabilitate an athlete with this injury, one must understand the biomechanics of both the sport and the individual athlete.

Anatomy

The spinal column descends from the skull to the pelvis with 7 cervical vertebrae, 12 thoracic vertebrae, and 5 lumbar vertebrae. The articulation of the adjacent-level vertebrae occurs via the intervertebral disk in the front and the facet joints in the back (Figure 1). The lumbar vertebrae end on the sacrum, which is a fused V-shaped vertebra that

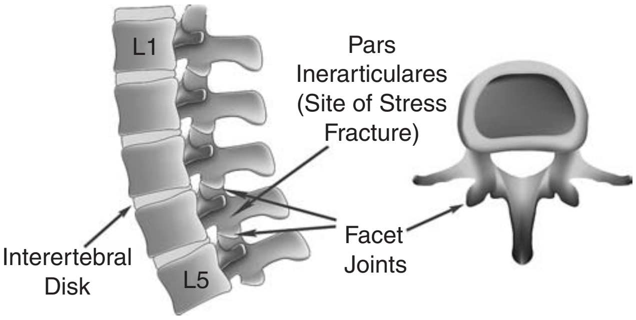

Figure 1 Lumbar Vertebrae (*lateral view*) and Single Vertebra (*top view*)

Source: Illustration by Michael d'Hemecourt.

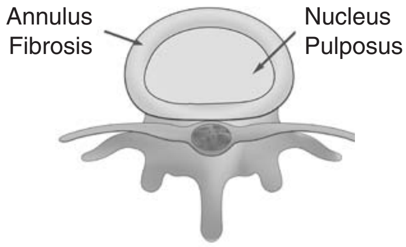

Figure 2 Cutaway View of Intervertebral Disk, Showing the Nucleus Pulposus at the Center, Surrounded by Annular Ligaments

Source: Illustration by Michael d'Hemecourt.

articulates with the pelvis to transfer forces from the trunk to the legs.

The disks become progressively larger from the cervical spine down through the lumbar spine. The disks provide shock absorption to the spine as well as motion. These disks are composed of three basic components: the annular ligaments on the outside (annulus), the colloidal gel (nucleus pulposus) on the inside, and the end plates of the vertebrae above and below. The *annulus* is composed of well-organized ligamentous sheaths (10–20 layers; Figure 2). The *nucleus pulposus* is a hydrous gel with few cells and some inflammatory enzymes. The *end plates* are at the top and bottom of the vertebrae, where the disk attaches. Since there is no blood supply to the disk, the end plate provides the nutrition to the disk by way of hydrostatic pressure during motion. In the child and adolescent athletes, these end plates are composed of soft growth cartilage and are susceptible to injury.

The disks are round and crescent shaped, with the posterior curved away from the posterior spinal column. The one exception is the lowest disk at the lumbar-sacral juncture (L5-S1), which is round. In the adult, the disk has the weakest ligamentous constraints on the posterolateral side, where the nerve roots exit. As such, a rupture here will affect the nerve. Conversely, the child and young adolescent may rupture into the soft end plate growth cartilage.

Etiology

A slipped disk represents a herniation of the nucleus through a tear in the outer annular ligaments. When a small isolated tear occurs, the nucleus stays in place except for mild bulging. This annular tear will appear as an intense white line on some magnetic resonance imaging (MRI) scans. This is called a high-intensity zone (HIZ) and has been correlated with pain.

When the annular tear is more complete, a herniated disk will occur with expression of the nucleus material through the tear in the annulus. The slipped disk may be subdivided into a protrusion, an extrusion, and a sequestration. A protrusion occurs with a partial focal tear of the ligaments, and there is a broad-based disk protrusion of the nuclear gel. An extrusion represents a complete focal annular ligament tear with a more narrow-based gel extrusion, but it remains in contact with the central gel (Figure 3). A sequestration occurs when this extrusion separates from the disk.

Risk Factors

Risk factors include smoking, obesity, genetic factors, lack of core conditioning, hard labor, and sedentary lifestyles. A genetic component is felt to be one of the most important considerations. Certain motions in sports are highly associated with disk involvement due to the biomechanics of the sport. When the spine is loaded in flexion, the disk on the front of the lumbar spine is placed under the greatest pressure. Examples of this loaded flexion include wrestling, power lifting, and crew (catch phase). Cycling can also load the spine in flexion when the fatigued cyclist loses the normal lordosis or sways back and slumps forward.

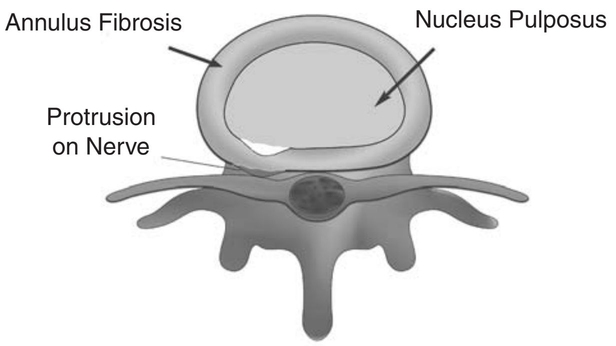

Figure 3 Herniated Disk, Showing Extruded Part of the Nucleus Pulposus Impinging on the Pathway of the Nerve Root

Source: Illustration by Michael d'Hemecourt.

The cervical disk may rupture in the wrestling take-down position. Collision sports such as American football and rugby also have some association to disk rupture due to direct impact and torsional loads. Long-distance cyclists place the spine in extension with a strong shear force, which can also cause disk rupture. Up to 40% of cyclists will complain of neck pain after a week of riding.

Clinical Presentation and Evaluation

The athlete with the disk herniation will present with pain either centrally or peripherally into the extremities. A herniated disk may occur next to the nerve roots. When it affects the nerve roots, pain and weakness of muscle groups in the distribution of the nerve supply may occur. In the neck, this will often produce symptoms along the shoulder, scapular, arms, or hand. In thoracic disk herniation, the symptoms will often distribute to the anterior chest or abdomen. In the lumbar spine, the distribution involves the buttocks, thighs, lower leg, and/or feet. These radiating symptoms are called *radicular symptoms*. They may be secondary to nerve compression from the mechanical bulk of the herniation or simply nerve irritation from leakage of inflammatory enzymes from inside the disk. Conversely, when the disk does not affect the nerve roots, there will be central pain in the neck, upper back, or lower back, depending on the level involved. This is called *axial pain syndrome*.

Disk herniations in the cervical spine mostly occur at the lowest cervical levels: C5-C6 and C6-C7. These levels produce symptoms into the arms and hands. Similarly, the lower lumbar spine is also affected, L5-S1 and L4-L5, which can affect the lower legs and feet. Thoracic disks are very uncommon but usually occur in the lower thoracic spine.

The peripheral pain often far exceeds the central neck or back pain. Certain motions are often provocative of the symptoms, while other motions will relieve the symptoms. Neck pain is often aggravated by activities that place the neck in hyperflexion or hyperextension. Classically, the cyclist or computer worker with the neck extended and chin forward will suffer aggravation of symptoms. Chin retraction may alleviate the symptoms. Lumbar or thoracic pain is often aggravated in the sitting or bending forward posture. In some cases, lumbar extension will relieve the pain.

It is essential to inquire about any worrisome red flags in the athlete that may prompt an immediate imaging evaluation. These would include loss of ability to hold the urine or stool, fever, chills, weight loss, weakness of an extremity, or constant night pain. In the absence of these, full imaging would be warranted if the symptoms last for longer than 6 weeks in the adult or 3 weeks in the young athlete. An MRI scan is usually the most appropriate imaging method to detect disk disease, but a CT scan is useful if the MRI scan is not possible.

Treatment

Treatment is based on the acuity of onset and the level of neurologic involvement. If there are signs of nerve root involvement, the progression is slower but usually follows a specific sequence. During the first few days, there is relative rest with utilization of analgesics. Rest should not exceed more than a few days. As the initial inflammation quiets, the subacute phase of isometric strength is used, where the core muscles or upper trunk muscles, if the neck is involved, are activated without motion. This often involves the use of calisthenic exercises, such as bridges for the lower back. Gradually, more dynamic low-resistance exercises are used, with progression of resistance as tolerated. Finally, as the athlete regains full strength, the sport-specific phase is started, with conditioning aimed at simulating sport-specific motions with attention to proper form. It is important to realize that cervical spine disk involvement typically requires more gradual progression initially as motion is poorly tolerated.

Because the herniated nucleus of the disk includes inflammatory components, an anti-inflammatory medication is very useful along with analgesics. In refractory cases, epidural injections of corticosteroids are very useful in accelerating the recovery phase. The adolescent athlete will often benefit from bracing to allow better rehabilitation.

Finally, surgery may be considered in three situations: (1) progressive muscle weakness, (2) loss of bowel or bladder control (emergent), and (3) refractory symptoms. The latter situation is somewhat subjective. In cases of severe pain, this may be as early as 6 to 8 weeks. In moderate cases, it may be months before surgery is considered. If surgery is needed, the athlete with a simple disk excision may possibly be ready for sports participation in 6 to 8 weeks.

Pierre A. d'Hemecourt

See also Back Injuries, Surgery for; Cervical Disk Degeneration; Intervertebral Disk Disease; Lower Back Injuries and Low Back Pain; Musculoskeletal Tests, Spine; Neck and Upper Back Injuries

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Snapping Hip Syndrome

Coxa saltans, or *snapping hip,* is a condition in which one feels a snapping sensation with movement of the hip. This may be accompanied by an audible pop and sometimes pain. There are three types of coxa saltans: external, internal, and intraarticular. Coxa saltans is common between the ages of 15 and 40 and is more often found in women. It is particularly common in athletes and dancers who undergo repetitive twisting motions about the hip.

Anatomy

The hip joint is the junction between the pelvis and the thighbone. The bony anatomy involves a ball-and-socket joint, with the head of the femur (thighbone) comprising the ball and the socket being formed by a groove in the pelvis called the acetabulum. This groove is deepened by a rubbery structure around the rim, called the *labrum*. The cartilage between these two surfaces serves as a cushion to absorb the stress transmitted between the surfaces.

There are many muscles around the hip that attach on the femur and pelvis. The muscles attach to the bones via ropelike fibrous tissue called *tendons*. Some of these tendons cross over bony prominences, which are normal protrusions in the bone. The natural consistency of healthy tendon fibers allows them to glide over these prominences with joint movement. Between the tendons and the bony prominences, there are sacs of fluid, called *bursae*, which minimize the friction between the bones and the tendons that pass over them.

The *iliotibial* (*IT*) *band* is a fibrous structure that extends from the pelvis to the knee. It functions to flex and rotate the thigh. The *gluteus maximus* is a large muscle that extends across the buttock and rotates the hip. Both the IT band and the gluteus maximus muscle cross over a bony prominence on the femur called the *greater trochanter*. This bony prominence can be easily felt in most people by pushing on the bone over the outer aspect of the thigh. With normal walking motions about the hip, the muscles and tendons glide over the greater trochanter without difficulty.

The hip flexor complex is a set of muscles formed by the iliacus and psoas muscles, which fuse to form the iliopsoas tendon. This connects the spine with the femur and functions to flex the hip. The iliopsoas tendon crosses over the hip joint, near the groin. In doing so, it passes in a groove next to the femoral head (the ball of the hip joint) and over the pelvis at a point called the *iliopectineal eminence*. With hip movement, the tendon slides from one side of the femoral head to the other (see Figure 1).

Causes

Coxa saltans can be divided into three different types. The external and internal types are generally caused by overuse and irritation of the muscle groups, which can lead to snapping of the tendons over the bony prominences. The two types are distinguished by their locations and the groups of muscles and tendons involved. The third type is intraarticular, in which the snapping can originate from within the hip joint itself. This is much less common but tends to be a more serious problem.

The external snapping hip is the most common type. Here, the IT band or the muscle of the gluteus maximus can catch and cause a snapping sound while crossing over the greater trochanter during normal motions of the hip. This may be due to tightening of these structures, caused by lack of flexibility. This can also happen if the greater trochanter protrudes more than normal. If the underlying bursa becomes irritated, one may have pain associated with the snapping as well.

In the internal snapping hip, the snapping occurs in the groin. The iliopsoas tendon becomes irritated due to overuse and can catch or snap while moving over the iliopectineal eminence or the femoral head. Inflammation from overuse of the iliopsoas tendon, called tendinitis, is often found in athletes or dancers who repetitively flex and externally rotate the thigh.

The intraarticular type of snapping hip stems from problems within the hip joint itself. This type is more commonly related to an injury rather than to chronic overuse. One of the more common injuries in this category includes labral tears, which are injuries to the cartilage rim around the joint. Other injuries may cause pieces of the cartilage, termed *loose bodies,* to be entrapped within the hip, causing a clicking noise with movement.

Symptoms

Typically, snapping hip develops over the course of months or years. Patients will describe an audible snap that is often reproducible at the time of the exam. An associated bursitis may cause tenderness or pain accompanying the snapping sensation.

In contrast, patients with intraarticular snapping may note a sudden onset of symptoms, usually

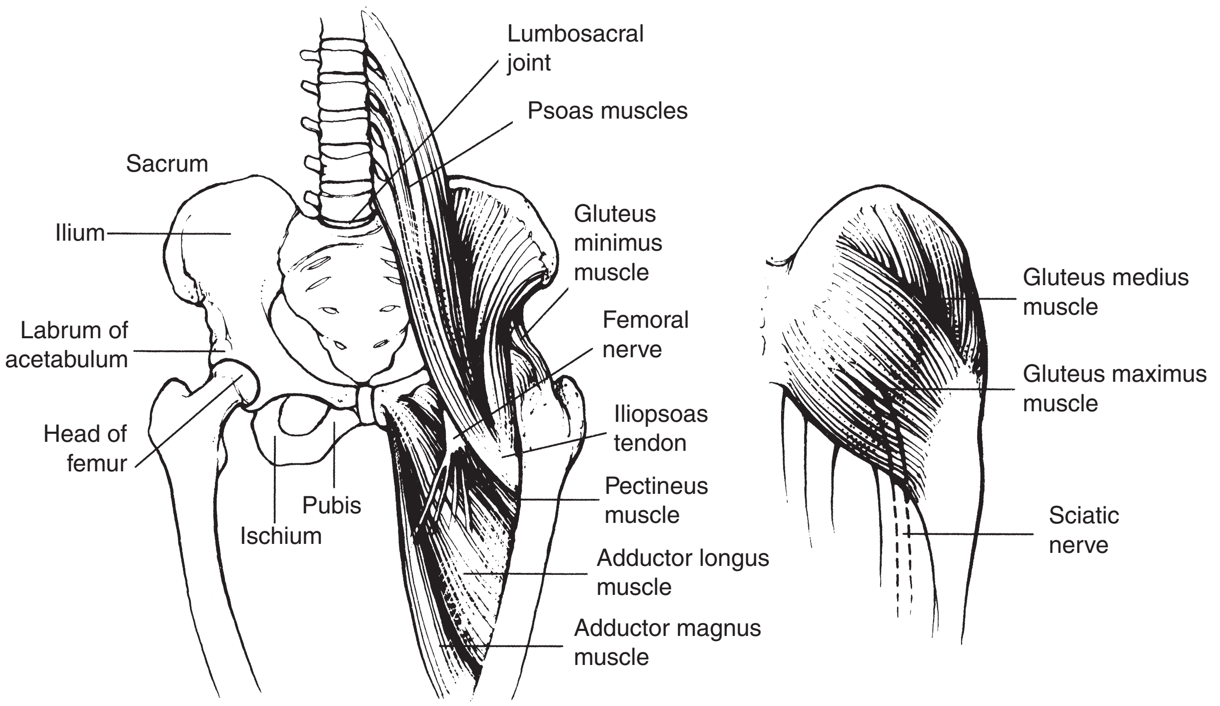

Figure 1 Anatomy of the Hip, Pelvis, and Groin

related to a specific injury. Patients may describe their symptoms as a clicking rather than an audible snapping sound. This type is more likely to be associated with pain and may also include locking or catching sensations while moving the hip.

Diagnosis

The diagnosis of internal and external coxa saltans is typically made by observing the snapping and identifying the area involved. The external type can be diagnosed by feeling the snapping of the IT band over the greater trochanter as the patient flexes and extends the hip. Tightness of the IT band on examination may also point to this diagnosis. Those with internal snapping hip will have similar symptoms near the iliopsoas tendon in the groin.

X-rays are generally not helpful in the diagnosis of snapping hip, as the soft tissues involved cannot be assessed on radiographs. Magnetic resonance imaging (MRI) may be used to rule out injuries to the intraarticular cartilage but are not routinely obtained.

Rarely, internal and external coxa saltans may require diagnostic procedures. An ultrasound test is a noninvasive method of using sound waves to image the hip. Iliopsoas bursography (injecting dye into the bursa) can also be used to diagnose internal coxa saltans. Both techniques can detect abnormal motion of the tendon over the bony prominences, as well as identify any inflamed bursal tissue or tendons.

Treatment

Nonsurgical Treatment

The typical treatment for most cases of internal and external snapping hip is nonoperative, as the snapping motion of the hip is considered normal. If symptoms persist and become painful, then the physician may give a cortisone injection directly into the area that is inflamed. Rest, anti-inflammatory medications, and physical therapy will also help stretch and heal the muscles and tendons that are irritated. Most patients respond well to conservative therapy and are able to resume normal activities within 6 to 12 weeks.

Surgery

Surgical treatment of the internal and external types of snapping hip is rarely indicated, but it may be performed in cases of severe and persistent symptoms. Surgical treatment of external coxa saltans involves removal of the inflamed bursa and lengthening of the IT band. This removes tension from the tendon and allows it to glide over the bony prominences without snapping.

For the internal type, a similar procedure involving lengthening of the iliopsoas tendon is available. This can be done through a small incision in the groin or through a procedure called arthroscopy, which is a minimally invasive method using small incisions and a camera. Both procedures are typically done as outpatient surgeries.

Unlike the internal and external types, intraarticular causes of snapping hip generally require surgery. Many types of disorders contribute to intraarticular snapping, and these require therapies that are specific to the disorder. In cases of injury to the cartilage, surgery may be indicated to either remove or repair the problem. Most procedures of the hip are done with a standard open surgery. However, the advent of arthroscopic surgery has provided a minimally invasive way to address many of these problems.

After Surgery

Physical therapy after surgery depends on the type of surgery that is performed. Tendon-lengthening procedures will cause some hip weakness for several weeks until the muscle begins to heal. The first few weeks of physical therapy should focus on protecting the hip and reducing pain with range-of-motion exercises, as well as exercises to increase control of the leg. At the rate determined by the physician, therapy should later progress to strengthening and gait training, with eventual return to normal activities.

Miho J. Tanaka and Dennis E. Kramer

See also Hip Flexor Tendinitis; Iliotibial Band Syndrome; Trochanteric Bursitis

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Snowboarding, Injuries in

The origin of snowboarding is somewhat debatable, yet most historians of the sport agree that the first snowboard was made out of a plywood plank in 1929 by M. J. "Jack" Burchett, who strapped the wood to his feet using a clothesline and horse reins. Some historians attribute snowboarding's origins to Sherman Poppen back in 1965, when he tinkered with the invention of a toy called a "snurfer" for his daughter, which consisted of two skis bound together and then tied a rope to the front for steering downhill to mimic the combined components of surf and snow. The early entrepreneurs Jake Burton Carpenter and Demetrije Milovich designed and produced the modern-day version of snowboards. The sport's modest beginning can be traced back to the production of snowboards and bindings back in 1977, although the sport did not really flourish until the 1990s. It made its Winter Olympic Games debut in 1998 in Nagano, Japan, and is today the fastest-growing winter sport with more than 3.4 million participants. There is some speculation that snowboard will take over skiing in popularity by as early as 2015.

The Sport and Its Equipment

The appearance of the snowboard on the scene was initially met with much resistance, for its enthusiasts were characterized as rebellious teenagers in baggy clothing, looking for an outlet that was devoid of respect and etiquette and disrupted the natural flow of skiing. Snowboarding in its infancy appealed to surfers, skateboarders,

Snowboarding is the fastest-growing winter sport, with more than 3.4 million participants.

Source: Eric Limón/iStockphoto.

and backcountry idealists, who were often characterized as overly aggressive youths with a foolhardy attitude that negatively affected safety, although such characterizations might be attributed to age bias.

Snowboarding is typically identified in three major categories according to the particular style of riding or the type of board: (1) freestyle board, (2) freeride (all-mountain) board, and (3) Alpine (carving) board. Each board is uniquely characterized by the specific construction technique, the material of the board, and the unique shape, pattern, and flex for each specialty.

A freestyle snowboard is typically the one a beginner uses because it is more stable, wider, and more forgiving and thus easier to ride. Due to the softer flex and the shape, as well as the uniform symmetry, forward motion can occur in both directions, as is typically seen in the twin tip boards. These boards are meant for performing tricks such as airs, spins, grabs, and fakies (motion in a reverse direction) in terrain parks and half pipes. The contrasting directional freestyle snowboard has a stiffer tail than the nose of the board and is more beneficial when primarily going in one direction with a particular footed dominance.

Freeride (all-mountain) snowboards are typically the most popular type of snowboard, as illustrated by the sheer number of sales of these types of boards. These specialty boards are designed to be used for powder snow conditions and are identified as all-terrain mountain boards because they can be used not only on the hill but also in a terrain park and in a half-pipe. Freeride snowboards have a more directional shape, with a tail that is narrower, shorter, and flatter than the tip of the board. The stance position of these boards also differs in that they are typically offset toward the tail of the board. These boards are soft enough for beginners to maneuver in the snow and stiff enough to carve some turns.

Alpine (carving) snowboards, in contrast, look like larger versions of skis with a shoveled front tip and asymmetric appearance. They are characterized as carving snowboards because of their ability to make sharp, clean turns and their great edging abilities on hard snow for stability and speed. Alpine snowboards are designed for high-speed performance, such as in racing, and for moving in a more uniform direction; therefore, they are much more difficult for beginners to manage and learn due to the advanced body mechanics required to maneuver on harder snow surfaces.

Competition snowboarding includes numerous sporting events that are sanctioned by the International Ski Federation, abbreviated in all languages as FIS. FIS was founded on the eve of the first Olympic Games in 1924 in France with 14 member nations. Today, 107 National Ski Associations constitute the membership of FIS, which oversees the World Cup competitions and the World Championships. The federation organizes a number of disciplines in alpine, parallel giant slalom (PGS), and freestyle, which include subcategories such as half-pipe, snowboard cross, big air, and, more recently, slope style.

Following the collapse of the National Association of Professional Snowboarders in 1990, five nations and 120 athletes established the International Snowboarding Federation (ISF) with the goal of keeping the officiating by riders and for riders. The ISF set the standard for snowboarding competition, which contributed to snowboarding becoming an Olympic sport in 1998. Controversially, the International Olympic Committee did not recognize the ISF as the governing body for snowboarding but recognized FIS as the sport's official governing body. Many snowboarders boycotted the Olympics as a result, concluding that the FIS rules were inappropriate for snowboarding. The FIS has maintained its control over the Olympics, giving credence to the position that snowboarding is a discipline of skiing and not its own, individual sport.

Injuries in Snowboarding

The pattern of injuries in snowboarding differs from that in skiing primarily because of significant differences in sport mechanics. Skiing typically demonstrates a significant number of injuries, from torque-type injuries such as tears of the anterior cruciate ligament (ACL) of the knee to other lower extremity pathologies induced by the free rotation and often uncontrollable trauma of the lower extremities during falls. Snowboarding, in which two feet are planted firmly on the same board, does not demonstrate the same frequency of rotational torque-type injuries. Instead, falls on an outstretched arm typically lead to more injuries of the upper extremity. The wrist is the most commonly injured body part, with wrist fractures accounting for almost half of upper extremity injuries. Wrist sprains and elbow fractures, along with clavicle fractures and shoulder dislocation, contribute to the upper extremity percentages being predictably higher for snowboarders than for skiers.

The use of helmets has reduced the frequency of head injuries to between 30% and 50%. Injuries to the head typically occur as a result of a direct blow to the head when making contact with the hard-packed snow surface. As a result, the injuries that occur are less serious in nature and are limited to head lacerations, contusions to the head, and milder versions of concussions. There continues to be a reduction in the number of fatalities due to increased helmet use, which has been shown to drastically reduce the severity of concussions and minimize the number of skull fractures as well as lessen the likelihood of severe closed-head injuries. The overall rate of injury has increased for snowboarding more recently due to the greater number of beginners who have taken up the sport. The research literature has clearly demonstrated that the highest frequency of injury is typically found in young novice snowboarders. More than 50% of novice skiers have the greatest likelihood of being injured in their first season of snowboarding. Additional contributing factors include failure to wear appropriate protective gear or receive appropriate instruction. Injury prevention is of extreme importance in snowboarding and entails the selection of specific gears such as wrist guards, elbow guards, back protectors, and tailbone butt protection along with helmets and proper boot fitting and equipment maintenance.

Boots and bindings are also of particular interest in snowboarding due to the different types of styles. There are three styles of boots: (1) soft, (2) hard, and (3) hybrid. Most of the boots today are softer in form and function, making it easier to maneuver specific snowboard moves due to the increased flexibility of the boot material. Hard boots are typically used only for racing and are the most common cause of boot type injuries and fractures. Most bindings on snowboards are nonreleasable and are made of plastic molding, with buckles to strap the boots onto the boards. The number of ankle injuries has been reduced due to the advanced technology of boots and bindings, but fractures remain the predominant ankle injury. The most common fracture is the so-called snowboarders' ankle, which is a fracture of the lateral process of the talus and is often undiagnosed on a typical X-ray. Treatment of a nondisplaced fracture typically consists of casting for 6 to 8 weeks. Displaced fractures are usually characterized by a displacement of 2 millimeters and are typically treated by open reduction internal fixation repair of the bone tissue.

Other common injuries in skiing that are less serious but still debilitating include frostbite, dehydration, and sunburn. Sunburn results from ultraviolet radiation and not from heat. Sun exposure on cold snowy days without any protection often results in sunburn, particularly in young children. Sunburn prevention should be practiced when skiing at any time. Hypothermia results when the core body temperature drops below 95 °F. Exposure to cold environments, particularly wet, windy conditions, can lead to rapid loss of body heat. Recognizing the signs and symptoms of hypothermia, such as confusion, slurred speech, fatigue, exhaustion, shivering, and loss of motor control, necessitates immediate action. The key is to eliminate the exposure and warm the individual. Hypothermia can often lead to cardiac arrest, so observation is also of great importance. Frostbite is literally frozen body tissue. Children are at a much greater risk than adults because they lose heat more rapidly and are often reluctant to protect against exposure. Treatment typically includes removing wet clothing, warming the exposed body parts in warm water, and preventing additional exposure. Following an appropriate treatment strategy and medical care are advised.

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Soccer, Injuries in

The physical demands of soccer can result in a wide variety of injuries to athletes. Youth and adult soccer players of all skill levels are at risk for both traumatic and overuse injuries. The types of injuries that may occur during soccer participation include sprains, strains, contusions, abrasions, fractures, and head injuries.

Mechanisms of Injury

Both contact and noncontact injuries occur during soccer participation. Contact injuries may result from contact with another player or equipment (i.e., ball, goal post). Noncontact injuries occur due to the high frequency of pivoting, running, and jumping activities performed by soccer players. Contact injuries more commonly occur during games, whereas noncontact injuries are more common during practice. For injuries that result in missed playing time, injury rates for both men and women are higher during games than during practice.

Acute Lower Extremity Injuries

The majority of soccer injuries occur in the lower extremities, with ankle sprains and knee ligament injuries occurring most frequently. Muscle strains of the hip adductors, hamstrings, and quadriceps are also very common. The contact nature of the sport also increases the frequency of contusions and abrasions to the lower extremities.

Ankle

A common ankle injury in soccer is a lateral ankle sprain. The ligament most commonly injured in an ankle sprain is the anterior talofibular ligament; this is caused by forced ankle plantarflexion and inversion. The calcaneofibular ligament is the second most commonly injured ligament in a lateral ankle sprain, followed by the posterotalofibular ligament. When the foot is forced into dorsiflexion and eversion, the deltoid ligament on the medial aspect of the ankle can be injured.

A high ankle sprain is a more severe type of ankle sprain. In this injury, the ligaments above the ankle (the syndesmosis) are torn. A high ankle sprain includes injury to the anterior inferior tibiofibular ligament, posterior talofibular ligament, and interosseous ligament. Pain at the ankle with compression of the tibia and fibula above the ankle (squeeze test) or a Maisonneuve fracture (proximal fibula) are positive findings of a high ankle sprain. High ankle sprains that are determined to be unstable are treated with stabilization of the fibula to the tibia with one or two screws while the injury heals.

When evaluating an athlete with an ankle sprain, the possibility of a Jones fracture (at the base of the fifth metatarsal) must also be considered.

Knee

Knee ligament and meniscal injuries result from pivoting, rapid direction changes, rapid deceleration motions, or contact with another player. Knee ligament injuries can occur with or without meniscal damage. Soccer players, especially women, are at a high risk for noncontact anterior cruciate ligament (ACL) injuries. The ACL is injured when the lower extremity is in a position of femoral internal rotation, genu valgum, and tibial external rotation. A valgus stress to the knee will injure the medial collateral ligament (MCL). Less commonly injured is the lateral collateral ligament (LCL). LCL injuries result from a varus stress to the knee. Multiple ligament knee injuries can occur with higher forces (see Figure 1).

Chronic Lower Extremity Injuries

Excessive amount of running during soccer can lead to chronic, overuse injuries. Achilles and patellar

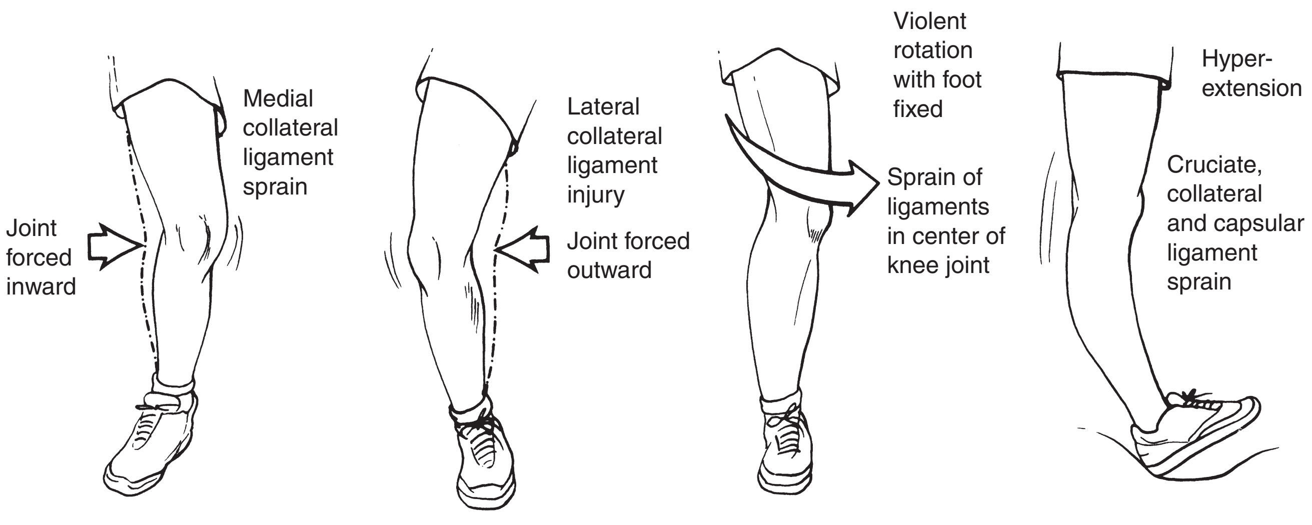

Figure 1 Knee Ligament Injuries

Notes: Which of the knee ligaments are injured depends on how the injury occurs. The most common mechanisms of knee injuries and the specific ligaments that most often get damaged are shown in the figure in each case.

tendinitis are common in adult soccer players. Although rare, stress fractures can develop from factors such as a hard playing surface, poor shoe wear, improper mechanics, and training errors.

Upper Extremity Injuries

Although not as common as lower extremity injuries, upper extremity injuries do occur during soccer. Direct contact with another player or a fall on an outstretched hand can result in upper extremity injuries, including acromioclavicular joint sprains, clavicle fractures, glenohumeral joint dislocations, elbow sprains and dislocations, and wrist sprains.

Injuries to Skeletally Immature Athletes

Year-round training combined with a high number of training hours increase the risk for injury in any sport. In a skeletally immature athlete, the apophysis, an ossification center where a tendon attaches to the bone, can be injured by traction forces or from a sudden muscular contraction. The forceful running and kicking motions during soccer play can cause avulsion fractures of the pelvic apophyses, including the anterior superior iliac spine (ASIS), the anterior inferior iliac spine (AIIS), the ischial tuberosity, and, less commonly, the pubic symphysis and the iliac crest. An avulsion of the ASIS is due to a forceful stretch or contraction of the sartorius muscle, whereas an avulsion of the AIIS is related to the rectus femoris muscle.

In addition to an acute avulsion fracture, overuse-type injuries to the apophysis can also occur from excessive running and jumping in young soccer players. Repetitive traction forces cause inflammation at the apophysis, known as *apophysitis*. Common sites of apophysitis in soccer players include the tibial tuberosity (Osgood-Schlatter disease), calcaneus (Sever disease), inferior pole of the patella (Sinding-Larsen-Johannson), and iliac crest.

Head Injuries

Concussions during soccer play most often result from player-to-player contact but may also occur from contact with the playing surface or goal post. Although there has been some concern that the repetitive low-impact stress of heading the ball may possibly have injurious effects to the brain, there is no conclusive evidence for this. Heading the ball is considered a safe skill when done properly.

Return to Sports After an Injury

Once an athlete has sustained an injury, a qualified health care professional should assess the athlete to determine if he or she is ready to return to play. The athlete should be painfree, have no swelling, have full range of motion, and have normal strength testing done before considering return to sports. Isokinetic strength testing can be used to objectively identify and evaluate smaller strength deficits that are not detectable by manual muscle testing. Sport-specific functional testing also needs to be performed to determine if the athlete is ready to return to sports. Lower extremity functional testing should progress from bilateral to unilateral and from straight-plane activities to multiplanar activities. Examples of functional tests include balance/proprioceptive tests, broad jump, unilateral hop test, triple hop test, crossover hop test, and sport-specific drills (running, lateral movements, pivoting, and cutting maneuvers).

Injury Prevention

Although the risk of contact and noncontact injuries with soccer participation cannot be eliminated, it is possible to decrease the risk of injury. General guidelines to minimize the risk of injury during soccer participation include the following:

- Always perform a proper warm-up (general cardiovascular warm-up, dynamic stretches, sport-specific drills).
- Perform lower extremity stretches to improve muscle flexibility.
- Wear proper shoes.
- Use protective equipment.
- Maintain good field conditions.
- Maintain an adequate fitness level (muscle strength and cardiovascular endurance).
- Have proper hydration and nutrition.
- Enforce game rules.
- Properly supervise young athletes.

Since most soccer injuries occur to the lower extremities, training programs specifically for minimizing the risk of ankle and knee injuries can be beneficial. Training programs may include all or any combination of the following components: warm-up, lower extremity stretching, lower extremity and core strengthening, proprioceptive and neuromuscular training, plyometrics, and sport-specific agility drills.

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Speed, Agility, and Speed Endurance Development

The goal of all team and individual sports athletes is to have great speed, agility, and speed endurance to outperform their opponents. To develop these conditioning adaptations to their full potential, the athletes have to be ready for rigorous training and must be disciplined when not training to allow the body to recover properly; otherwise the risk of injury from overtraining is imminent. This entry will provide insight on the necessary training variables to become not only faster but also faster for longer periods and more agile on the court, field, or floor.

Defining Speed, Agility, and Speed Endurance

To develop speed, agility, and speed endurance, it is necessary to assess the needs of the athlete in the sport or position that he or she plays. First, it is important to fully understand each of these terms.

Speed

Speed is the ability of an athlete to create a lot of velocity through recruiting muscles rapidly. Speed must come from all joints and segments of the body working sequentially (see the entry Resistance Training). Pure speed is often seen in sports as straight-line speed, such as the 100-meter (m) sprints or a fastball in baseball. Just as important for the ability to develop speed through the segments of the body is developing the muscles, joints, tendons, and ligaments for the rapid deceleration of the joints once the speed-producing movement is complete. If the body is not able to decelerate itself, then serious injury will occur. For example, if the muscles did not decelerate when throwing a fastball, then the arm would likely dislocate.

Agility

Agility, also known as sports speed, is an athlete's ability to rapidly accelerate, stop, and change directions and accelerate again. Agility training is a priority for sports played on a field in team settings such as soccer, rugby, and American football. The focus of agility training should be on the ability to slow down the body rapidly and accelerate the body as fast as possible in as little time possible. Developing speed for sports requires an immense amount of power coupled with eccentric and concentric strength of the antagonist and agonist musculature.

Speed Endurance

Speed endurance means that the athlete is able to sustain high velocity and able to reproduce the acceleration and deceleration multiple times without a significant drop-off in power output multiple times for more than 6 to 7 seconds. This would mean that the athlete has a high threshold for pyruvate-lactate accumulation. The dominating energy system supporting high-intensity work for durations greater than 10 seconds is the anaerobic glycolysis system.

The rate of force development (RFD) implies how quickly a movement can be produced. This is the measure that will indicate how successful off-season conditioning is for the athletes on the field. To increase the RFD in a movement pattern that ultimately increases speed, agility, and speed endurance, the ratio of fast-twitch glycolytic (Type IIa) muscle fibers and fast-twitch oxidative (Type IIab) muscle fibers to slow-twitch oxidative (Type I) muscle fibers need to increase more on the side of Type IIa.

This will result in an increase in the impulse production, according to Steven Plisk (in *Essentials of Strength Training and Conditioning,* 2000), by generating a greater force in a given time or by improving the RFD.

Speed Technique Development

For an athlete to reach his or her true potential in top-end speed, form, or technique must be developed along with the athlete's muscular strength and power. A needs analysis for the athlete's power profile is necessary before prescribing the correct ratio of volume to intensity of conditioning for the athlete's respective sport or position. The ratio of pure speed drills to strength-speed drills for an offensive lineman in football would be drastically different from that of a wide receiver. Coaches must conduct video analysis of the amount, if any, of contact the athlete has with opposition, how many quick changes in direction the athlete executes in competition, how long it takes for the athlete to decelerate, and the number of times that an athlete performs sprints at maximal effort. To develop the optimal speed endurance program, the strength coaches need to know what the work-to-rest ratio throughout the sporting event typically is. Once the aforementioned data have been collected, the team strength coach and team head coach are able to combine the information on movement and performance with the information on skill of the athlete(s). Having this information all together allows the coaches to develop the best sequence of movement, performance, and skill drills and the best work-to-rest ratio between these types of drill before, during, and after a given competitive season to optimize on-field performance and to decrease the risk of injury.

Sprinting technique drills will teach the athlete the correct form to use when accelerating away from an opponent or when trying to catch or pass an opponent. If the athlete's form is impaired, more energy than is necessary is being expended to produce a movement, ultimately causing fatigue. In the case of sprinting, two variables dictate the forward projection of the athlete's body: stride length and stride frequency. Stride length is the distance between the feet each time a foot makes contact with the ground. If the athlete's stride length is too long or too short, it will take more effort than is necessary. The length of the stride will vary depending on the athlete's height and limb length. Stride frequency is the number of times that the legs can turn over in a maximal sprint. Steven Plisk points out that both stride frequency and length are equally important when an athlete is accelerating; however, the stride rate has the most influence at maximal speed. When the athlete's speed picks up, impulse production becomes more dependent on the ability to create force rapidly.

There are a multitude of techniques that coaches use to develop straight-line speed. Form drills such as "high-knee drills" and "butt-kickers" train the hips and knees in the rapid turnover. Different styles of skipping and bounding help with stride length frequency development. Hill training is another very useful training modality. When athletes run up gradual hills, their leg drive technique is developed; focusing on high knee strikes will develop impulse. Running down gradual hills will assist the athlete in increasing stride frequency and stride rate. It is important to note that the incline/decline of a hill should not be too steep so that the athlete's form is not compromised.

Agility Technique Training

Having great straight-line speed does not necessarily translate into great sports speed. The most important components in developing sports speed are acceleration and deceleration development. Stability and efficiency are essential when training the right body mechanics so that the transitions between stopping, quick change of direction, and acceleration are more balanced. Agility training can be taught through form drills, using set parameters such as cones, lines, or poles. Agility training can also be taught openly through reaction drills such as mirror drills, tag, or reacting to cues from the coaches, such as a whistle or signal indicating a change of direction. Agility must be trained in all plains of motion—sagittal, frontal, and transverse—to provide the athlete with the necessary conditioning for movements that may occur during competition.

Speed and Agility Training Methods

There are several ways to develop an athlete's speed and agility. Hill training is one example. Others include the following:

- Footwork and form drills
- Assisted and resisted sprinting drills
- Resistance training
- Flexibility training

Footwork and Form Drills

Footwork drills and form drills are necessary to conduct at the beginning of training sessions. Examples are ladder drills, crossovers, turns, and cuts using traffic cones. The body is sensitive to neuromuscular feedback and is able to adapt to the detailed drills so that the body keeps the correct form even when it is fatigued.

Assisted and Resisted Sprinting Drills

Hill training is a form of assisted running because the athlete is running with the downward pull of gravity. Another way to train an athlete to run faster is to use stretched rubber tubing with a harness around the athlete's waist or torso to pull him or her forward. Rubber tubing may also be used for resisted running. When the tubing stretches, it creates greater resistance. Parachutes, running uphill, and weighted sleds that are pushed or pulled by the athlete are other tools to provide resistance while running forward, backward, and laterally.

Resistance Training

General total body strength and power training must complement the aforementioned drills. Resistance training must be used to maintain overall kinetic chain symmetry and to prevent overtraining injuries that may occur. (For more information on the proper methods of training and sequencing, see the entries Periodization and Resistance Training.)

Flexibility Training

Strength and conditioning coaches must know the work-to-rest ratio in the sport of the athletes they are training to optimize the adaptations of speed endurance. Sports such as rugby and soccer have different work-to-rest ratios in comparison with American football or ice hockey. Rugby and soccer athletes do not have as much opportunity to rest between high-intensity plays unless play has been stopped due to penalty, injury, or halftime. It is important to note that the energy system that must be trained, and is affected the most by speed-endurance training, is the anaerobic glycolysis system. When repetitive bouts of high-intensity sprints or tackling occur in rapid succession, lactate-pyruvate concentrations increase in the body's cells because the mitochondria (the organelle responsible for cellular respiration) are unable to clear out the by-products produced. Implementing the aforementioned speed and agility drills with little or no rest at submaximal (80–90% of maximal intensity) efforts when the athletes are slightly fatigued will produce a positive adaptation for speed endurance. Having the athletes perform obstacle courses that integrate footwork drills with sprints and low-intensity jogging are popular ways to train athletes for improved speed endurance. (For more information on speed-endurance training, refer to the entry Interval Training/Fartlek.)

Samuel L. Berry

See also Cardiovascular and Respiratory Anatomy and Physiology: Responses to Exercise; Exercise Physiologist; Exercise Physiology; Interval Training/Fartlek; Periodization; Resistance Training

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Speed Skating, Injuries in

Speed skating is a sport that held its first competition over 300 years ago in the Netherlands. There are two disciplines in speed skating—long track and short track. Short-track skaters race in a pack around a smaller oval, while long-track skaters race in their own lane. All speed skating athletes are at risk of sustaining injuries during training and competition, although the short-track skaters are at higher risk.

History

Ice skating originated thousands of years ago, when Scandinavian men attached animal bones to their footwear to help glide across frozen waterways. The metal blade was invented in the late 1500s. That helped spur the popularity of speed skating. The first world championship was held in the Netherlands, with four events: 500, 1,500, 5,000, and 10,000 meters (m). Short-track speed skating began in the early 1900s.

Olympic long-track speed skating debuted in 1924, at the first Winter Games in Chamonix, France. Short-track speed skating was introduced at the 1988 Winter Games in Calgary, Canada. Both disciplines are governed by the International Skating Union.

Long-Track Speed Skating

Equipment

The body of the ice skate is called the boot. Many elite athletes have custom boots created using the molds of their feet. The boot is constructed with leather and carbon graphite. A long-track boot is cut lower on the ankle than a short-track boot.

The blades are made from carbon steel. They are very flat and thin, allowing long-track skaters to glide in long, straight lines. Most elite skaters use a clap skate. This blade detaches at the heel and has a spring-loaded hinge at the ball of the foot. As the skater lifts his or her foot, the hinged blade remains on the ice longer. This improves speed and traction.

Most skaters wear eye protection to prevent tearing and drying secondary to wind. Many also wear skin-tight clothing with hoods designed to make them more aerodynamic. Long-track speed skaters do not wear helmets.

Events

Long-track speed skaters race counterclockwise on a two-lane, 400-m oval. The winner is the person with the fastest time. The athletes will cross over, or change lanes, every lap on the back stretch. Thus, long-track skaters do not race in the same lane.

The traditional events are the 500, 1,000, 1,500, 3,000, 5,000, and 10,000 m. A 100-m sprint event has been recently added. Team pursuit is also a newer event. In team pursuit, each team begins at opposite points on the track. A team of three or four skaters race in a single-file line, allowing the skater in the back to conserve energy by not having to break the wind. They rotate positions in the single-file line to try to get the fastest time for six to eight laps.

Short-Track Speed Skating

Equipment

The short-track boot rises higher on the ankle than a long-track boot to give more stability with turning.

The blades are made from carbon steel. They are shorter and thicker than long-track skates to withstand the stress of turning. The blades are offset and bent to allow skaters to lean into turns without allowing the boot to contact the ice.

All skaters must wear protective gear. This includes a helmet, a neck protector, cut-resistant gloves, knee pads, and shin guards. Most skaters wear protective eyewear, which also helps prevent tearing. The skaters wear tight-fitting skin suits like the long-track skaters. However, many short-track suits are made of Kevlar, making them cut resistant and safer.

Events

There are normally four to six skaters racing counterclockwise around a 111-m oval. The outcome of the race is not based on time, but the first person to cross the finish line is the winner. The racers all share the same space, so there is great potential for contact between skaters, falls, and subsequent collision into the wall of the rink.

The main events are the 500-, 1,000-, 1,500-, 3,000-, and 5,000-m relay. In relay events, there are usually four teams of four skaters. The skaters must take at least one lap on the track, but there is no set number of laps that each racer must complete.

Injuries

Very few data are available on injury rates in speed skaters. While injuries can occur during training and competition, it is thought that short-track skaters are at higher risk of injury due to the higher risk of collision. There is a higher risk of asthma symptoms due to exposure to cold, dry air. As with all athletes who compete in international events, there is a risk for infectious disorders common to the region hosting the event, as well as common viral syndromes.

Skaters are at risk for overuse injuries, particularly of the lower extremities. This is secondary to the repetitive motions required for the sport. Back pain can be secondary to mechanical and muscular issues, as well as lumbar disk disease. Hip pain is commonly related to iliotibial band tendinopathy and groin strains. Knee pain is frequently secondary to patellofemoral pain syndrome and patellar tendinopathy.

Foot and ankle disorders frequently occur due to irritation from the skate boot. A tightly laced boot can apply pressure to the muscles around the ankle, causing Achilles tendinopathy, as well as "lace bite," which is a common name for tendinitis of the anterior tibialis and toe extensor muscles. Due to the amount of time spent in the skates, athletes may develop athlete's foot or tinea pedis. Interestingly, peroneal tendinopathy is seen much more frequently in short-track speed skaters due to the force required to complete sharp, high-speed crossover turns.

All speed skaters are at risk for arm and wrist injuries such as contusions, fractures, and sprains secondary to falls. Short-track skating carries a higher risk for upper extremity injuries due to the high-speed, pack-style skating format. This leads to a great deal of contact and can precipitate falls. Therefore, injuries such as shoulder dislocations, concussions, and lacerations (from contact with the skate blades) are seen much more frequently in short-track speed skaters.

Injuries can potentially be reduced by ensuring that athletes use proper equipment and maximize their off-ice conditioning. Athletes should also warm up well and remain warm throughout their practice and competition. It is important that they have well-maintained skates that fit properly. The blades should be sharpened frequently to improve traction. Of course, loose clothing that can get caught on the blades should not be worn.

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See also Ankle Injuries; Concussion; Conditioning; Contusions (Bruises); Knee Injuries; Lower Leg Injuries; Tendinopathy

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Spinal Cord Injury

Spinal cord injury (SCI) is a rare but potentially devastating occurrence in sports. In the general population, motor vehicle crashes are the most common cause at around 40%. Sports and recreation injuries are responsible for about 12% of

SCI, diving accidents being the most common cause in this category. However, any sport involving speed, contact, or collision presents an environment where SCI can occur. This includes, but is not limited to, ice hockey, football, motor sports, and cycling.

Anatomy

The spinal cord extends from an opening in the base of the skull (the *foramen magnum*) to the second lumbar vertebra in the lower back. Beyond this level, it continues as a bundle of nerve roots called the *cauda equina,* or "horse's tail" because of its appearance. The spinal cord resides in a canal formed within the bony vertebral column of the back, which provides protection for the delicate tissue.

The spinal cord is divided into 31 segments or levels: 8 cervical (neck), 12 thoracic (upper and midback), 5 lumbar (lower back), 5 sacral, and 1 coccygeal. The latter two are so named because the nerve roots for these segments exit the spinal canal via the sacrum and coccyx, which are part of the pelvis. Viewed in cross section, each segment gives rise to motor nerve roots that exit the spinal cord from the front and sensory nerve roots that exit dorsally (from the back). The motor and sensory roots from each segment combine to form a spinal nerve corresponding to that segment, one to the left and one to the right. These spinal nerves carry motor and sensory information from the spinal cord to the periphery and back.

The spinal cord's job is to transmit information from the brain to the body (e.g., coordinating the motions of one's arm and hand to pick up a cup) as well as to transmit feedback from the body to the brain (once one's hand grasps the cup, this sensory information is sent to the brain to let it know that it can proceed with the instructions to lift it from the table).

Etiology

Most injuries to the spinal cord are traumatic in origin. Traumatic SCI frequently occurs in association with dislocation or fracture of the surrounding vertebrae in the neck or back. However, a special consideration in the pediatric population is SCI without radiographic abnormality (SCIWORA), where the increased flexibility of the developing spinal column allows for trauma to be inflicted on the spinal cord in extreme neck flexion or extension without any apparent fracture or dislocation occurring. In such an injury, the spinal cord is contused (bruised) by the impinging vertebrae. Depending on the severity of the impingement and the resulting inflammatory reaction, this injury can be temporary or permanent. The clinical exam will reveal diminished motor or sensory function consistent with the segmental level of injury. However, X-ray and computed tomography (CT) will reveal no bony or ligamentous injury. Magnetic resonance imaging (MRI) may show the cord contusion itself, but diagnosis and management are best guided by the clinical exam.

SCI may also be the result of compression of the cord, without actually cutting or bruising it. This is possible in the case of dislocation of vertebrae, progressive narrowing (stenosis) of the bony spinal canal, bulging of one or more intervertebral disks (the cushions between vertebrae), or several other, more progressive conditions. Spinal cord function is affected by the direct compression and/or by reduced blood flow and nourishment of the cells. Clinically, a patient will have reduced sensory and motor functions consistent with the level affected, which may be progressive over time, starting with an occasional "numbness and tingling" and progressing to complete loss of motor function.

Injury Patterns and Symptoms

SCI is a broad term referring to any injury that either temporarily or permanently prevents the spinal cord from performing its job of transmitting motor and sensory information between the brain and the rest of the body. More specific terms are generally defined by anatomic location of the injury (paraplegia vs. tetraplegia) and its severity (complete vs. incomplete). Paraplegia is an injury to the spinal cord in the thoracic, lumbar, or sacral segments. The most obvious deficit is loss of function of both lower limbs; however, sensation will be affected below the level of the injury (e.g., an injury at T2 would affect sensation from the chest all the way to the feet). Tetraplegia is an injury to the cord in the cervical region, which results in loss of function of all four extremities. In addition, an injury in the cervical region can have profound effects on one's ability to breathe, as motor control of the diaphragm originates from the C3-C5 segments. Both paraplegia and tetraplegia cause varying degrees of loss of bowel and bladder function.

Complete SCI is usually associated with a severe vertebral fracture and/or dislocation, with bony fragments transecting, or cutting, the spinal cord. While paraplegia and tetraplegia are considered complete injuries (as evidenced by loss of both motor and sensory function), it is also possible to have an incomplete injury where only motor or sensory function is lost or where only one side of the body is affected. For example, *anterior cord syndrome* is characterized by loss of motor function but preservation of many sensory functions, which travel primarily in the back of the spinal cord. *Brown-Sequard syndrome* is a unique condition in which the left or right half of the spinal cord is transected. Given the manner in which motor and sensory information cross from right to left at different levels, a person with this injury characteristically presents with loss of position sense and motor function on the same side of the body as the injured side of the cord and loss of pain and temperature sensation on the opposite side.

Treatment

Although research is ongoing, there is little to be done to repair a damaged spinal cord. Therefore, management is directed toward pain control, prevention of worsening of symptoms, and recovery of function where possible. This is done through medication, physical therapy and rehabilitation, and, in some cases, surgery.

Medication is an area of intense debate and research. There is little disagreement regarding pain control. Analgesics ranging from acetaminophen and nonsteroidal anti-inflammatory drugs such as ibuprofen to narcotics such as morphine and hydrocodone are all useful in managing pain. However, care must be taken to prevent development of dependence on these drugs and to avoid side effects associated with overuse.

Steroids have played a role of varying prominence with regard to treatment of SCI. More recent evidence shows that steroids may be helpful in reducing the secondary effects of acute SCI, that is, the inflammatory reaction that occurs after injury and is thought to be responsible for some of the longer-lasting damage. Significant improvements in neurologic outcome have been demonstrated with initiation of steroid administration very soon after injury (within 8 hours). However, more research needs to be done in this area to determine efficacy. Also, steroid administration has side effects that may outweigh the neurologic benefits, such as immune suppression, which makes a patient susceptible to severe infection.

Physical therapy can be very effective in both mild and severe injury. In more mild cases, a therapy regimen that improves flexibility may reduce compressive symptoms, including helping a herniated disk "slide" back into place. Also, strengthening of the core muscles (e.g., abdominal muscles and the muscles that stabilize the spine) may be helpful in reducing symptoms by providing an "assist" to the vertebrae and intervertebral disks. In more severe cases where a lasting motor deficit is present, intensive therapy and rehabilitation can help a patient learn to use different muscle groups to compensate or even help a previously affected muscle group and nerve pathway to "relearn" its function.

Another therapy receiving much attention is the intravenous (IV) infusion of very cold saline solution. Saline with a normality of 0.9% has a similar salt concentration to the water present in the body and is used routinely for IV hydration. With regard to SCI, as well as to prehospital management of trauma patients in general, the infusion of ice-cold saline drops the body's temperature by several degrees, which is thought to reduce the body's oxygen and energy demands and is a way to preserve the delicate and damaged tissue, particularly until more definitive management can be initiated. Cooling is another way to reduce the postinjury inflammatory reaction. However, more research must be done to determine the precise effects that produce benefit as well as the appropriate algorithm for implementation. For example, there is a fine line between enough cooling to preserve tissue and too much cooling that triggers failure of, and damage to, other organs. Also, following injury there is likely to be a time after which the benefit of cooling is lost and the effect is perhaps detrimental.

Surgical repair of the spinal cord itself is not currently possible. However, there are several procedures to treat persistent insults to the spinal cord. Laminectomy is a procedure in which the lamina, part of the vertebra that forms a protective ring around the spinal cord, is removed. This allows swelling of the cord or surrounding the soft tissues to bulge outward and away from the spinal cord rather than compress the cord. The more bone that is removed, the more unstable the spine becomes, increasing the risk for future injury to the spinal cord. As a result, spinal fusion may be required. Supplemental bone tissue (from either the patient or another donor) is used to stimulate the body's own bone building to fuse the adjacent vertebrae and limit their mobility. The goals are decreased pain and risk of further injury but at the expense of overall mobility of the back.

Because of the risks associated with surgery in general and because of the likelihood of reduced function after surgery, decompressive procedures are reserved for cases of severe neurologic compromise (particularly in cases of direct pressure on the spinal cord) or in cases where more conservative therapy provides little or no improvement.

Prognosis

SCI is a potentially devastating injury. Incomplete injuries generally have a better prognosis than complete injuries. Patients with complete injuries have a 5% or less chance of recovery, which drops to nearly 0% at 72 hours postinjury. Preservation of some sensory function indicates a 50% chance of recovering the ability to walk. In terms of long-term survival, the mortality rate has steadily improved over the years, mostly as a result of gains in infection control with early diagnosis and better treatment of conditions such as pneumonia and urinary tract infection.

In general, the sooner the SCI individual receives acute intervention (i.e., decompression, steroids, IV cooling) and is stabilized, the better the prognosis. Acute interventions aimed at curbing the inflammatory response are believed to prevent secondary tissue damage and, therefore, further loss of function.

Regarding return to play following a sports-related SCI, the first consideration is whether the patient is dealing with a permanent deficit and that deficit's implications in sports selection and participation. Second, the patient's injury and functional exam must be stable in the case of a permanent deficit or completely resolved in the case of a temporary deficit.

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Splenic Injury

Although the liver is the most frequently injured abdominal organ, the spleen is the most frequently injured organ in sports and the most common cause of death due to abdominal trauma in athletic activity.

Epidemiology and Biomechanics

Injuries to the spleen can result from a direct force to the abdomen, especially the left upper quadrant; from a sudden deceleration when the hilum is torn; or by displacement of lower left rib fractures. Any of these mechanisms are possible in high-speed or contact sports. The mechanism of splenic injury was explored in one study of downhill skiers. In high-velocity or high-impact collisions, for example, with a tree, a chairlift pole, or a snow fence, multiple trauma was always present (fractures or damage to multiple organs). Skiers were unable to move at the scene, and splenectomy resulted in 5 out of 6 cases (83%). With low-velocity or low-impact collisions, often just a single organ was involved. Such injuries resulted from falls on ski trails, on moguls, or on tree stumps or rocks. Presentation in these cases was often delayed for hours while the individual continued skiing. Splenectomy was necessary in 5 of 12 cases (42%). An investigation by Machida and colleagues reported in their 1999 article, published in *Injury,* showed a significantly higher abdominal injury rate in snowboarders than in skiers. Injuries to the kidney, liver, and spleen were seen in both. In snowboarders, riding mistakes after jumping and subsequent falls were responsible for 31.6% of the abdominal traumas. Skiers were more likely to have a collision as the mechanism for their abdominal injury.

Clinical Presentation

Initially, the pain of splenic injury is sharp, followed by a continued dull, left-sided ache. The patient may complain of radiating pain to the left or right shoulder secondary to free intraperitoneal blood irritating the diaphragm. Splenic rupture is associated with abdominal pain, left shoulder pain (the Kehr sign), or periscapular pain.

Physical exam is neither sensitive nor specific for splenic injury. Because the spleen's capsule can contain bleeding, the signs of splenic injury are often delayed, thereby rendering physical examination unreliable and subsequently hindering diagnosis. The abdomen may be distended. Left-upper-quadrant abdominal tenderness may or may not be accompanied by peritoneal signs, such as generalized tenderness, guarding, and rebound tenderness. There may also be tenderness over the left 10th, 11th, and 12th ribs. Indicators of hypovolemia, such as tachycardia and hypotension, are worrisome signs.

Imaging

Patients with an appropriate mechanism or pain should have a computed tomography (CT) scan taken. CT staging of splenic injury does not predict the need for laparotomy, nor does it correlate with clinical outcome; however, it remains the most accurate method of diagnosing initial injury.

Management

The most important determinant of nonoperative management of splenic rupture is hemodynamic stability, including determination of hematocrit. Exploratory laparotomy is indicated if the individual is hemodynamically unstable, and splenectomy is performed if the injury is extensive or the hemorrhage is otherwise uncontrollable.

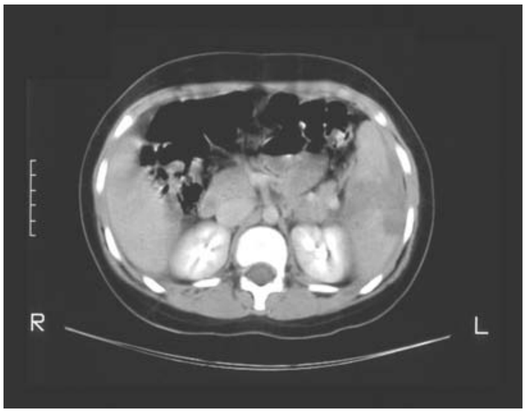
Nonoperative management of splenic injuries consists of careful hemodynamic monitoring, frequent physical and laboratory examination, and, most important, strict bed rest.

In many ways, the management of splenic injury parallels that of the liver. Hemoglobin and hematocrit from a complete blood count can indicate the extent of any blood loss. An elevated leukocyte count may be present if a subcapsular hematoma has developed. Diagnostic peritoneal lavage (DPL) classically is positive if any significant bleeding has occurred from injury to the spleen or other abdominal organ.

Given a stable course, the CT scan should be repeated after 5 to 7 days and should show stabilization or improvement of the injury. Avoidance of contact sports is recommended for up to 4 months after injury. This is determined largely by the severity of the injury seen on a CT scan and its resolution (Figure 1). Most authors recommend at least a 3-month period of physical activity restriction, with the first 3 weeks after hospital discharge spent as "quiet" activity at home. Nonoperative splenic management seems to be more successful in children (90%) than in adults (70%).

Epstein-Barr Virus, Infectious Mononucleosis, and Splenomegaly

By age 30, 90% of the population has been exposed to the Epstein-Barr virus, which causes infectious mononucleosis. This may frequently be unrecognized, particularly in children. From 1% to 3% of college students are affected each year. The peak incidence is in 15- to 24-year-olds. A recent study using physical exam alone reported splenomegaly in 8% of patients with infectious mononucleosis. In comparison, a study using ultrasonography demonstrated that 100% of patients with infectious mononucleosis had an enlarged spleen; physical examination detected the abnormality in less than 20% of the same cases. These studies indicate that physical exam alone is an insensitive tool to diagnose splenomegaly in the setting of infectious mononucleosis.



CT scan illustrating heterogeneous signal indicating splenic fracture. A transverse section is shown at the thoracic level, viewed from below. The spleen is located to the right side, adjacent to the ribcage.

Source: Courtesy of David Mooney, M.D., Children's Hospital Boston.

Infectious mononucleosis causes the splenic architecture to become distorted, making the spleen susceptible to rupture from any increased abdominal pressure, even from sneezing or coughing. Splenic rupture in infectious mononucleosis occurs in 0.1% to 0.2% of cases, with the highest estimate being 0.5%. The timing of this complication is predictable, being noted in the first 3 weeks of the illness. Splenic rupture is unusual beyond 3 weeks from the onset of symptoms (headache, sore throat, and fever). The prodromal period is not considered when determining the onset of the illness.

This complication fortunately is often not fatal. Splenectomy is necessary in some instances, although nonoperative management is often successful. Treatment should be individualized. There is no evidence to suggest that corticosteroids reduce spleen size or shorten the duration of the illness.

Return to Sports

The appropriate time to allow an athlete with infectious mononucleosis to resume his or her activity is determined by the duration of the symptoms, as well as the presence of splenomegaly and the risk of splenic rupture. There is concern that contact trauma may precipitate splenic rupture. In a 1976 survey of college team physicians, the respondents identified 22 cases of splenic rupture. At the time of the trauma, 41% of these were diagnosed with infectious mononucleosis. Seventeen of the student athletes were participating in football. Most splenic ruptures in the setting of infectious mononucleosis, however, are spontaneous and not the result of contact.

Return-to-play recommendations in the literature have been varied. To protect the enlarged spleen, which should probably be assumed to be present in all cases, all strenuous activity should be avoided for the first 21 days. At this point, the athlete may start a graded aerobic program, avoiding contact, if the athlete is asymptomatic, afebrile, and does not have a palpable spleen. At 4 weeks, if the signs are equivocal or the athlete is at a high risk for collision, an imaging study such as an ultrasound should be considered. It should also be noted that normal spleen size has been directly correlated with athlete size; hence, a large athlete with an appropriately sized spleen may be mistakenly diagnosed with splenomegaly if the splenic volume/body mass is not considered.

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See also Epstein-Barr Virus, Infectious Mononucleosis, and Splenomegaly; Liver Conditions, Hepatitis, Hepatomegaly

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Spondylolysis and Spondylolisthesis

Spondylolysis is a type of stress fracture in the spine. The fracture occurs in the back of the bone, in an area called the pars interarticularis. The condition is the most common cause of low back pain in adolescent athletes and thought to be an overuse injury that results from repetitive microtrauma to the bone. The term *spondylolysis* originates from the Greek words *spondylo,* meaning "vertebrae" (or bone of the spine), and *lysis,* meaning "to dissolve."

A fracture of the pars interarticularis may become unstable, allowing the vertebrae to slip out of position. This slippage is called *spondylolisthesis*. Typically, the fifth vertebrae shifts forward in relation to the sacrum.

Anatomy

The spinal column consists of 24 bones arranged on top of each other. These bones, separated by fibrocartilaginous disks for cushioning, are called *vertebrae*. The vertebrae provide support and stability for the spinal column and are important for posture and movement.

Facet joints connect the vertebrae and allow them to move freely, resulting in flexibility and movement of the spine. Two other bones—the pedicle and laminae—form the bony ring that surrounds each vertebra. The area of bone that joins the upper and lower facet joints is called the *pars interarticularis*. It is often the weakest link between the pedicle and lamina.

The spinal column consists of three segments, which include 7 cervical vertebrae (in the neck), 12 thoracic vertebrae (in the upper back), and 5 lumbar vertebrae (in the lower back). The lumbar vertebrae are the thickest. The lumbar spine is connected to the pelvis.

Spondylolysis most commonly occurs in the lumbar spine, at the lowest lumbar (L5) vertebral level. Most fractures occur on both sides of the spine and are bilateral; however, they may be unilateral as well.

Causes

Spondylolysis in sports is caused by overtraining and overuse of the spine. Athletes who play sports that involve repetitive hyperextension (bending backward) and rotation of the back have a higher risk of developing spondylolysis than those who do not. Examples of these sports include ballet, gymnastics, diving, and figure skating.

Repetitive hyperextension puts a great deal of stress on the spine. When the spine is overextended, the pars interarticularis is especially vulnerable to these forces, and microtrauma in the bone can result. The body tries to repair these repeated small injuries, but sometimes the repair mechanism is overwhelmed by ongoing damage, leading to a stress fracture (Figure 1).

Sometimes repetitive hyperextension from sports weakens the bone so much that it results in spondylolisthesis. In children and young adults, the most common cause of spondylolisthesis is spondylolysis. Age is a significant risk factor in the development of spondylolysis due to spondylolisthesis.

Symptoms

The most common symptom of spondylolysis in athletes is low back pain that worsens with extension, especially while playing sport(s). Pain may be in one location or spread throughout other areas of the back. It is typically dull and aching, similar to a muscle strain. Symptoms are gradual in onset. Hamstring tightness is often present. Initial rest from sports and medication with nonsteroidal anti-inflammatory drugs (NSAIDs) temporarily reduce pain.

Patients with spondylolisthesis complain of muscle spasms and tightness resulting in difficulty with posture and walking. Muscle weakness, leg pain, and sphincter (a circular muscle that helps maintain constriction of a passage in the body) weakness; loss of feeling in the buttocks; and radiating pain from the spine down the legs may also occur.

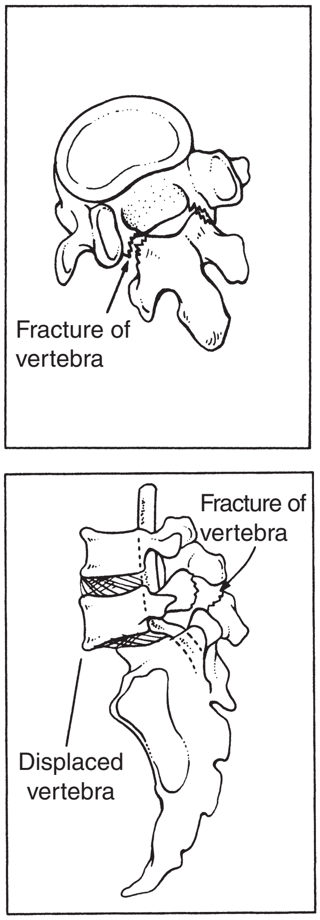

Figure 1 Spondylolysis and Spondylolisthesis

Diagnosis

History

A complete history and physical examination are the first steps in making a diagnosis. A history of the present illness should include the duration of the pain, whether the onset is gradual or sudden, the factors that improve or worsen pain, changes in muscle function, or difficulty with bowel or bladder functions. The presence of night pain may indicate a more serious underlying condition and should be excluded.

It is important to obtain a sport-specific history from the athlete. This includes the maneuvers required for the sport, how long the athlete has been experiencing symptoms, the intensity of the sport, and the level of involvement. Associated factors, such as increased training or growth spurt, should also be considered.

Physical Examination

The spine should be palpated for areas of tenderness, which may indicate the location of the fracture. Tenderness can occur in a part of or throughout the back. It is important to note that an injured athlete's postflexibility should be compared with his or her preinjury flexibility. Range of motion, such as bending forward (flexion) and bending backward (extension), should be tested. In athletes with spondylolysis, this is usually more limited and painful in extension. When the patient stands on one leg and bends backward, the opposite side may be painful. The weight-bearing side is consistent with the painful injured side. Hamstrings are generally tight. An exaggerated curve of the lumbar spine, referred to as *hyperlordosis,* is typical.

Diagnostic Imaging

When the history and physical examination suggest spondylolysis, X-rays are often the first step in imaging. This includes anterior-posterior (AP), oblique (angled), and lateral (side) views. Lateral views show the degree of slip and the angle of slip in spondylolisthesis.

Plain radiographs reveal how the vertebrae are positioned. These are useful in detecting fractures and slippage of the vertebrae. However, X-rays do not always show stress fractures, and more subtle fractures may be missed. In these instances, more advanced diagnostic imaging is necessary. A diagnostic test called a bone scan indicates increased areas of metabolic activity and bone turnover associated with stress fractures. The addition of single-photon emission computed tomography (SPECT) offers an even more sensitive test to detect bone stress. Early fractures not detected on plain radiographs are often shown on SPECT bone scans. When increased areas of bone turnover are present, computed tomography (CT) can be used.

CT identifies bone form and structure. It is used to determine the extent of the fracture as well as its healing potential. Fractures are classified or "staged" as early, progressive, and terminal. Early-stage fractures have the most healing potential.

Magnetic resonance imaging (MRI) offers the advantage of minimizing exposure to radiation while evaluating bony structure and edema (inflammation) in one test. It can also be used to rule out other causes of back pain, including disk problems.

Treatment

The main goal of treatment is complete healing of the fracture and a safe return to sports. Many athletes return to sports with a fibrous union, meaning that although they are asymptomatic, the fracture has not completely healed. This outcome has a favorable short-term prognosis; however, a bilateral bony union is more preferable.

Nonsurgical Treatment

Most athletes with spondylolysis are treated conservatively. Conservative measures include rest from sports, bracing, and physical therapy. It is important to encourage the athlete to be compliant with the treatment plan, particularly rest from sports.

Antilordotic bracing, physical therapy, and modification of activities are often prescribed. Bracing in general remains controversial among practitioners. The purpose of the brace is to reduce the forces on the posterior elements of the spine. Different types of braces are available. Physical therapy includes abdominal strengthening exercises, as well as stretching of the back and hamstring muscles. These exercises strengthen the back and core muscles and help improve lordosis/swayback.

NSAIDs may initially reduce pain. Nonimpact activities such as swimming and the elliptical should be encouraged in the initial treatment phase, as long as the patient does not have discomfort with these activities.

As symptoms improve, activity can be slowly increased. Caution should be taken not to return the athlete to sports too early as this could exacerbate the symptoms and delay fracture healing. The athlete can be slowly weaned from the brace if there is no pain with return to sports or provocative extension maneuvers during clinical follow-up.

In instances where conservative treatment has failed (the fracture has not healed and the athlete is still experiencing pain), electrical stimulation may be prescribed. It is thought that the electrical current stimulates bone cells to grow and divide, which accelerates fracture healing.

At periodical follow-up appointments, the health care professional should ensure that symptoms are improving and that the fracture is healing. The athlete should be painfree by history and with provocative extension maneuvers during the clinical evaluation. Computed tomography (CT) may be used to assess healing of the fracture.

Surgical Treatment

The decision to perform surgery is based on the failure of conservative treatment and the severity of the athlete's symptoms. Surgery is necessary if slippage continues to progress and the pain is so severe that it interferes with activities of daily living.

A spinal fusion is used for surgical stabilization. Bones are surgically fused, allowing them to grow together. This ensures that the bones and joints do not move or slip further. In this procedure, a bony bridge is created between the sacrum at the lower part of the spine and the area of slippage.

Surgery may also be performed to remove bone or other tissue. This takes pressure off the spinal cord or spinal nerve roots and is called *decompression*. A fusion and decompression may be performed together depending on the athlete's symptoms and slippage. After surgery, a brace is used and physical therapy prescribed to strengthen the core muscles. As with conservative treatment, caution should be taken to return the athlete to sports gradually and slowly.

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Sport and Exercise Psychology

In the past 30 years, sport psychology has been recognized as a distinct area of study in human behavior. Sport psychology is concerned with the psychological and emotional factors that influence both participation in sports and performance activities and the psychological effects derived from them. There are many dimensions to participation in sports, exercise, and performance activity that are influenced by psychological factors. Sport psychologists study motivation, personality, leadership, team building and cohesion, coaching styles, athletic identity, the psychology of injury rehabilitation, and variables related to achieving optimal performance. Sport psychologists work with individuals, teams, parenting organizations, coaches, and health care providers. The field has grown and has become integrated into the overall development of athletes and performers. Psychological factors are considered to be critical in achieving optimal performance after the talent playing field is leveled. Psychologists also contribute to understanding the effects that participating in physical activity has on psychological development, health, and well-being. While some sport psychologists work exclusively with athletic performance, many focus on the psychological factors involved in exercise—developing strategies to encourage sedentary people to exercise or evaluating the effectiveness of exercise as a treatment for depression. The field has been broadened and is now called *sport and exercise psychology.*

Sport psychology has two primary specialties: (1) clinical sport psychology and (2) educational sport psychology. A significant distinction is made in the field between the two. Clinical sport psychologists have extensive training in clinical and/or counseling psychology and have developed their skills to detect and treat individuals with emotional disorders. Clinical sport psychologists are typically licensed by state boards to practice and have augmented their training to include the subspecialty of sport and exercise psychology and the sports sciences. Educational sport psychology consultants have extensive training in sport and exercise science, physical education, and kinesiology. They also understand the psychology of human movement as it manifests in sport and exercise environments. Educational sport psychology consultants often provide "mental coaching" and psychological skills training. They are often called on to work with teams and individual athletes to teach anxiety management strategies, improve athletic confidence, improve coach-athlete communication, and build team cohesion.

History of Sport Psychology

The first known sport psychology laboratory was established in Germany in 1920. Coleman Griffith has been recognized as the father of this science in the United States. In 1925, he established the first ever sport psychology facility in the nation, the Athletic Research Laboratory. Griffith focused his research on various sport science and psychology issues in 1918, and he introduced the first university-level courses in sport psychology at the University of Illinois in 1923. Coaches showed interest in the psychological aspects of athletic performance in competition even before there was a science called sport psychology. The "pep talk" was highlighted by Knute Rockne—the football coach of the fighting Irish of Notre Dame—in the 1920s. Academic sport psychology was established by the mid-1960s. Physical education had become an academic discipline (now called kinesiology or exercise and sport science), and sport psychology had become a separate component within this discipline. Sport psychologists had also developed the applied side of their field and started to work with athletes and teams.

The field is thriving and vibrant, with many applications in sports, exercise, physical health, and sports medicine. Applied sport psychologists find their skills and application of knowledge helpful in many domains. In coach-training programs, the sport psychologist can help coaches understand the complex relationship between thought, emotions, motivational factors, and behaviors when an athlete is both acquiring a specific sport skill and applying it in athletic situations (with teammates, opponents, officials, and their coaches). Education is provided to help the coach understand the differences between using positive and aversive approaches to influencing behavior—as well as helping coaches use tools to assess their own effectiveness.

In sports medicine, the clinical sport psychologist is called on to treat injured or physically challenged athletes (those with overtraining, eating disorders, burnout, or overuse injuries or on post-surgical rehab) with emotional disorders. In addition, the sport psychologist assists athletes with the psychological process that goes alongside physical rehabilitation from acute and chronic sports injuries. The psychologist assists with the intricate recovery from sports concussions—both in the psychological assessment and in the counseling process. In addition, athletes often face challenges to their athletic identity when confronted with injuries and career-ending situations. The overall adjustment of the athlete is often improved by the specific skill set of a psychologist trained to work with athletes and high performers.

Sport psychology specialists provide consultation, education, and counseling to youth sports organizations. In the United States alone, an estimated 45 million children younger than 18 years are involved in school and extracurricular physical activity programs. Many children are intensively involved in organized sports. On average, youth sports activities require 11 hours weekly in the specific sport for about an 18-week season. Children are offered the opportunity through sports to participate actively in an activity that has meaningful consequences for themselves, their peers, their family, and the community around them. Most children peak in sports around age 12. Developmental psychology has provided the research to help us understand the critical periods for children that have important consequences on their self-esteem, body image, and social development. Hence, the youth sports experience can have important lifelong effects on the personality and psychological development of children. There are few hotter topics in parenting arenas than those surrounding the current challenges and opportunities facing youth sports. The professionalization and early specialization of young athletes have raised important questions about the developmental appropriateness of competition, sports selection, overuse injuries, overscheduled children, and the overzealous coach or parent.

Violence and Aggression in Sports

Another headlining topic that brings in the sport psychology consultant is violence and aggression in sports. Psychologists use the working definition of aggression as "any form of behavior directed toward the goal of harming or injuring another living being who is motivated to avoid such treatment." Psychologists further divide the term into two types of aggression. *Hostile aggression* has as its primary goal the infliction of harm or injury (physically or emotionally). *Instrumental aggression,* on the other hand, occurs as part of a non-harmful goal. A hockey check and a boxer's solid blow to an opponent's head are examples of instrumental aggression. Anger and violence often erupt in sporting situations because the line between instrumental and hostile aggression becomes blurry. Deaths have occurred when a player or spectator has not been able to regulate the aggressive arousal often stirred by high-contact play. The sport psychology consultant provides opportunities for coaches and players to address how to maintain the fine line between instrumental and hostile aggression and develop strategies for dealing with impulsive actions if an athlete, coach, or spectator feels out of control.

College Athletics and Sport Psychology

Many college athletic departments have begun to use and integrate the services of sport psychology consultants. College students and most student-athletes find themselves in a flux of emotionally taxing life transitions—some of which are predictable and result from the athletic commitments made and others that are developmental in nature. Student-athletes are a diverse group of individuals often trying to find their way in a more complex world than that of their predecessors. The commercialization of college athletics has brought new stressors to these athletes and their coaches. Navigating through the complicated National Collegiate Athletic Association (NCAA) rules and contractual obligations of scholarship monies leaves the student-athlete often unprepared for the stressful fallout from such a relished position. The NCAA has come to recognize the significance of counseling and mental health issues in the lives of student-athletes. The sport psychologist is available to assist with performance-based issues in the sports or game situation. He or she is also available to help the athlete balance academic demands, injury, time management, drug and alcohol use, and postcareer planning and transitions.

Professional sports and high-profile competitions such as the Olympics draw attention to the mental side of sports and have made it a "no-brainer" that the mind is often the defining factor in winning and losing. Specific mental skills are honed over time by well-trained and highly competitive athletes—including performing optimally under pressure, with optimal regulation of mood, anxiety, and thought—so that their performance is at a peak. When needed, the sport psychology consultant teaches a range of psychological skills to improve the mental side of the athlete's performance. These skills usually include goal setting, arousal control, self-talk, visualization, imagery, concentration and attention control training, and communication. These skills are used to address and improve performance issues. Sport psychology consultants also help athletes distinguish between performance enhancement and more problematic emotional issues. Depression, anxiety, adjustment disorders, and other mental health issues often affect athletic performance and can be disguised by the athlete or coach's perception that the struggle is performance based.

Exercise and Rehabilitation Psychology

Exercise psychology is an emerging field that separates itself somewhat from applied sport psychology but often shares many of the same underlying principles and tools. Exercise psychology is concerned with the application of psychological principles to the promotion and maintenance of exercise and physical activity and the psychological and emotional consequences of recreational physical activity. A field closely related to exercise psychology is rehabilitation psychology, which deals with the relationship between psychological factors and the physical rehabilitation process. Exercise rehabilitation is broader than recovery from sports injuries. It includes exercise rehabilitation from cardiac events, Type I and Type II diabetes, obesity, spinal cord injuries, and other medical events requiring exercise as a part of rehabilitation. Rehabilitation psychology also addresses the role of physical activity as a complementary strategy for treating disease and disability.

Some of the critical concepts in exercise psychology include studying the psychological antecedents of exercise behavior. While the American College of Sports Medicine recommends being physically active "most" days per week, the rate of exercise adoption and adherence is sluggish. They report that only 20% of adults engage in the minimal recommended amount of activity. Health care professionals frequently recommend exercise regimens as they relate to physical and mental health. However, compliance rates are often low, and adherence is primarily seen as related to psychological factors. In view of the alarming rates of inactivity in most industrialized nations, exercise psychology provides research and intervention strategies to address this epidemic. The U.S. Centers for Disease Control and Prevention have reported that lack of physical activity, along with poor diet, is responsible for at least 300,000 "preventable" deaths per year.

Exercise psychology relies on several theories and models to build understanding and interventions of physical activity behavior. At the core of the predominantly used exercise psychology theories is a common core construct—self-referenced thought. For example, self-determination theory begins with the basic assumption that individuals possess three primary psychosocial needs: (1) the need for self-determination (autonomy, self-dependent behavior), (2) the need to demonstrate competence, and (3) the need for relatedness. They hypothesize that individuals who exercise for reasons related to low self-determination (e.g., improving appearance) would be less likely to adhere to exercise interventions than someone who exercises for the pure pleasure of it. This theory predicts that improvements in intrinsic motivation to exercise would be aimed at enhancing an individual's sense of competence and autonomy in an environment that is supportive of satisfying social interactions. The systematic identification of the relevant psychological variables allows physical educators, trainers, and rehabilitation specialists to design a program making the best use of the strategies that should lead to long-term adoption of and adherence to exercise.

Practitioners and researchers in exercise psychology have extensively addressed questions related to mental health and physical activity. Considerable research has been done on the prevalence of depression, anxiety, and stress and the role that exercise can play in the alleviation of symptoms. Exercise is also studied for its self-esteem benefits and the overall contribution it makes to emotional well-being. Of course, the physical correlates of positive emotional well-being have been documented for decades and extend the value of this field well beyond the mental domain.

Sport Psychology in Sports Medicine

Only very recently has the sport psychologist also become part of an interdisciplinary orthopedic or sports medicine practice. There is a growing interest and need among sports medicine professionals to include the emotional component of the patient in rehabilitation from acute and chronic sports injuries. The sport psychologist works in coordination with sports medicine physicians, orthopedic surgeons, physical therapists, athletic trainers, nutritionists, fellows, and interns in training. Many sports injuries—both acute and overuse—respond well to a sport psychology counseling consultation. Acute injuries that are rather straightforward—broken bones, fractures, sprains, and strains—do not often even make it to the psychologist's office. Patients with recurrent or chronic injuries (e.g., multiple anterior cruciate ligament [ACL] injuries, which require long periods of rehabilitation; chronic back pain; regional pain syndrome) often suffer long periods of frustration, loss, and at times career-ending consequences. Counseling targeting the physical and emotional rehabilitation process often helps with injury recovery and overall adjustment. Children and adults who strongly identify with their sport/performance domain have difficulties making the transition to other activities while injured. As noted earlier, where an ACL repair can take up to 9 months before return to play is possible, athletes find it difficult to manage the unstructured time that is often consistent with being injured. Coordinating care around concussion management is particularly useful, as return-to-play decisions are often based on very subtle symptom recovery, requiring care and supervision from the treating physician or athletic trainer. In families with young athletes with concussions that last more than a few weeks, the psychologist can facilitate the implementation of physician recommendations for brain rest, academic accommodations, and modified physical activity. Based on anecdotal report, many young athletes recover more quickly from concussion symptoms when the treatment includes a psychological consultation.

Many athletes find the line between maintaining a healthy body weight and a strong performance weight to be a challenge. Sports medicine patients who are identified as possibly having nutritional, body image, or eating disorder issues are frequently referred for both nutritional and psychological counseling. The importance of maintaining a healthy body weight is significant for long-term performance issues in both men and women. Female athlete triad is a well-known condition for women who push the line in their athletic pursuits, creating conditions that prevent them from enjoying full physiological health. In many cases, these athletes do not resemble the psychological profile of the clinical eating disorder. In other cases, sports performance–based eating issues can become full-blown cases of anorexia and bulimia and need to be treated as such.

It is not always clear to the medical professional, athletic trainer, or coach as to when an athlete should be referred for counseling or psychotherapy. In much of the performance enhancement literature, most problems in performance are related to competition anxiety, motivational problems, and poor self-talk and concentration. However, sometimes athletes are struggling for reasons related to longer-term emotional issues that need to be identified. As noted at the beginning of this entry, there are sport psychologists who treat performance issues only and others with clinical/counseling training who can facilitate the care of athletes with emotionally based issues. When anxiety generalizes beyond the performance domain, it is usually indicative of issues that extend beyond athletic performance. Other kinds of issues facing athletes who benefit from counseling are identity issues, sexual orientation and homophobia, sexuality and human immunodeficiency virus (HIV)-related issues, eating disorders, alcohol and substance abuse issues, anger and aggression control, and relationship issues.

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See also Anger and Violence in Sports; Imagery and Visualization; Psychological Aspects of Injury and Rehabilitation; Psychological Assessment in Sports; Psychology of the Young Athlete

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Sports Biomechanist

This entry provides a brief overview of sports biomechanics and explains the role of the biomechanist in improving performance and understanding sports injuries. Specific examples highlight the importance of integrating sports medicine, biomechanics, and coaching.

Sports Biomechanics

Emerging as a subdiscipline of human movement biomechanics, the evolution of sports biomechanics has been driven by a desire to understand technique in sports performance. Interestingly, some early enquires were related to humans and animals and were based on how these groups organize their biological systems to produce successful performance. These investigations drove the development of theory and technology commonly used today. A famous example comes from the latter part of the 19th century, when the horse racing enthusiast Leland Stanford of California wanted to know if during a trot a horse had a flight phase. Eadweard Muybridge (1830–1904) used early photographic technology to address this question.

In general, the sports biomechanist considers technique from two interrelated perspectives: injury and performance. In the former, scientifically grounded methods are employed to understand and explain the biological responses to load and movement patterns that occur during sports and exercise; this type of biomechanics leads naturally to the clinical applications discussed in the entry Biomechanics in Sports Medicine. Using the same scientifically valid methodologies, the performance perspective presents a number of challenges; including identifying the underlying biomechanical determinants of successful performance, explaining effective and efficient techniques, and ultimately optimizing performance. The research challenge is often complicated by the need to maintain a high level of ecological validity.

In his keynote address at the International Society of Biomechanics in Sports (ISBS) conference in Salzburg, in 2006, former ISBS president Bruce Elliot highlighted the need for biomechanists to conduct research in a "real-world" meaningful environment. Collecting data during training and competition across a diverse range of activities requires flexibility in the methodology used. Fixed-volume analyses maybe used in sports such as gymnastics, where the performance occurs in a small volume, compared with sports such as ski jumping, skiing, and track-and-field events, where panning cameras maybe required. These factors complicate the research design and emphasize the need for innovation while maintaining internal validity, accuracy, and reliability. One result of this is that research has focused on certain sports that lend themselves to fewer complications (e.g., gait analysis compared with kayaking).

The principal ways in which sports biomechanics can help improve performance, develop the coaching process, and explain the most effective ways to train fall into a number of interrelated categories.

Mindset Development

Sports biomechanics can provide coaches with an accurate conceptual understanding of what constitutes successful technique, highlighting the key movement patterns, timings, and phases of the skill. This conceptual model allows the coach to effectively develop technique, strength, and conditioning exercise and preparatory activities. The development of a mindset is the first step in providing an effective coaching-biomechanics interface.

Coach Support

Working alongside the athlete and the coach, the sports biomechanist can provide direct feedback to the coach and/or performer. The feedback can range from basic timings—for example, in sprinting, split times at 5- or 10-meter (m) intervals are very useful—to the more complex kinematic (movement patterns) or kinetic (forces, joint forces) analyses. The important aspect of this feedback is that it is based on key performance variables that are directly related to successful performance. Issues can arise from the use of commercially available qualitative video analysis systems in terms of accuracy and reliability.

Feedback Enhancement

Another topical role that sports biomechanists may play is in the development of innovative technologies, athlete-worn sensors, and motion analysis system technologies that aim to provide meaningful biomechanical feedback to coaches and or performers. These systems are more scientifically grounded than the commercial qualitative video systems and provide precise and relevant information about performance; in addition, the information is presented in a sport-specific effective fashion.

Models of Performance

One important aspect of sports biomechanics is the development of performance or hierarchical models; these were first published by the late James Hay, who was also the former president of both ISBS and ISB (International Society of Biomechanics). These models are based on the underlying laws of human movement and aim to identify the key variables that have a causative effect on success. The models help explain the biomechanical requirements of skill and prevent the arbitrary selection of variables. Different levels of analysis are used within the development of these models, including:

- single-joint analyses,
- intersegmental coordination analyses, and
- joint kinetic analyses (moments, powers, work, energy).

Optimization of Performance

Another approach to understanding and explaining technique is through the use of forward dynamic analyses. Forward dynamics or computer simulation modeling provides a strong and useful tool that allows sports biomechanist to address questions in a completely controlled environment. This approach allows optimal technique to be determined and also predicts what may be possible to perform. Theoretically adapting performance to achieve specific performance criteria allows subject-specific optimal performance to be determined.

Conclusion

The future progression of sports biomechanics, specifically from the performance perspective, rests with the development of the coaching-biomechanics interface (CBI). Increases in effective technology and ecologically valid scientific enquiry will promote the development of the CBI. The integration of sports biomechanics, sports medicine, and sports coaching represents an evolution from a mono- to multidisciplinary research perspective and ultimately to an interdisciplinary approach.

Gareth Irwin

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Sports Drinks

Sports drinks are part of a giant multibillion-dollar industry whose products are marketed to the active athletic population. They are a varied group of noncarbonated beverages now widely used to provide energy, to avert fatigue, to enhance concentration, and, most important, to replenish exercise-related fluid, carbohydrate, and electrolyte losses associated with dehydration. The ultimate goal is to optimize athletic and academic performance through the use of sports beverages. However, sports drinks are not universally indicated or needed during exercise, particularly for short-duration, low- to moderate-intensity exercises. The energy derived from sports drink ingestion does provide a nutritive substrate for longer-duration exercise and aids in recovery from high-intensity workouts. Sports drinks must be differentiated from "energy drinks," which typically include nonnutritive stimulants such as caffeine, guarana, taurine, ginseng, carnitine, creatine, and/or glucuoronolactone, with varying amounts of carbohydrate, protein, amino acids, vitamins, sodium, and other minerals.

How Sports Drinks Provide Energy for Exercise

Sports drinks derive their "energy" primarily from carbohydrates, which fuel the metabolic pathways used during exercise, particularly by muscle and brain. Caloric energy comes from sugars such as glucose or fructose. After approximately 20 minutes of aerobic exercise, as the glycogen stores are depleted, blood glucose becomes an increasingly important energy source. Calories (cal; 1 cal = 4.2 joules) in sports drinks range from 10 to 70 per serving (14 grams [g] average per 240 milliliters [ml] or 8 ounces [oz]). There is much greater variability in the caloric content of energy drinks, ranging from 10 to 270 cal per serving. Sports drinks are designed to restore the fluids, carbohydrates, and electrolytes lost during intense physical activity. A carbohydrate sports drink of no more than 6% to 8% is needed to supply the requirements for this nutrient during moderate, prolonged, or strenuous exercise provided that adequate hydration is maintained. A slight rise in insulin is a natural response to ingestion of carbohydrate-containing foods or beverages. The insulin release that follows sports drink ingestion during exercise helps increase the rate of glucose uptake and use by working muscles to prolong the intensity and duration of exercise.

Appropriate Use

Copious ingestion of sports drinks can result in unnecessary or excessive ingestion of carbohydrates. High doses of simple carbohydrates can evoke the greatest insulin responses. For exercise of less than 1-hour duration, most of the energy is readily obtained from the glycogen stores and the metabolic breakdown of protein and fat. Therefore, the primary goal of fluid intake during exercise is to maintain adequate hydration. This should be easily achieved with water ingestion only. Furthermore, sports drinks should not be used during lunch or snacks as a replacement for low-fat milk or water. In this setting, the higher-calorie sports drinks contribute to excessive caloric intake as well as insufficient intake of other essential nutrients, increasing the risk for overweight and obesity in children and adults, not unlike soda ingestion. Low-calorie sports drinks will not contribute to the risk of overweight or obesity and yet do not provide adequate carbohydrates for intense exercise; therefore, their role, if any, in the athlete's diet is yet to be determined.

During prolonged and intense exercise, the body can experience fatigue and impaired sports performance without adequate energy substrates available. A switch from hydration with water only to a carbohydrate-electrolyte beverage after the initial hour of vigorous exercise is appropriate to replenish the calories and electrolytes lost while rehydrating and to maintain exercise intensity. Continued exercise with water intake alone can have negative consequences on the body due to the depletion of the essential nutrients required to maintain the body's energy balance and function. Athletes often prepare for intense exercise by eating a diet high in carbohydrates. But during exercise, eating solid food is usually not an option. Sports drinks provide an easily digested carbohydrate source for the body, thus allowing the athlete to maintain optimum energy levels. Table 1 provides a recipe to prepare your own custom sports drink.

Table 1 Make Your Own Custom Sports Drink

Ingredients
¼ cup sugar
¼ tsp salt
¼ cup water
¼ cup orange juice (not concentrate) or a combination of 100% fruit juices
2 tbsp lemon juice
3½ cups cold water
Directions
1. Dissolve the sugar and salt in the water.
2. Add the juices and the remaining water; chill. Makes four servings.
Caloric Content
Per 8-ounce serving: 50 calories; 12 grams carbohydrate; 110 milligrams sodium

Note: 1 ounce (oz) = 28.35 grams (g); 1 calorie (cal) = 4.2 joules.

Sports Drinks Versus Water

Water is an essential part of our daily diet. During exercise, water is the appropriate choice for hydration for 60 minutes or less of exercise and does not need to be ingested in the form of a sports drink or other beverage. Clothes, diet, medications, illnesses or chronic conditions, fitness level, and acclimatization influence the body's sweat rate and risk of dehydration. Sweat rates vary greatly among individuals but can reach 1 to 3 liters (L)/hour. Environmental conditions such as heat, humidity, intensity, and duration of exercise all affect the quantity of water needed to maintain a euvolemic state. Exercise-induced dehydration is caused by a mismatch of fluid lost in sweat and adequate fluid replacement. Excessive dehydration is associated with premature fatigue, impaired sports performance, and an increased risk of heat-associated illness. Sports drinks offer advantages to promote fluid intake because their flavor, color, and sodium and carbohydrate content all increase the natural tendency to drink during exercise. Offering fluids that are slightly cooled (59–72 °F or 15–22 °C) to athletes also appears to improve their overall fluid intake.

Electrolytes

Sodium and potassium are essential nutrients in our diet. Sodium maintains blood volume and helps preserve the balance of water in the cells. Athletes with low sodium levels may feel nauseated, experience painful muscle cramps, or feel disoriented or confused. Potassium helps regulate muscle control, nerve function, and blood pressure. Potassium works with sodium to keep the body's water in balance. Sweating causes blood sodium levels to rise, which prompts thirst. However, thirst is not generally a sufficient stimulus to maintain fluid balance during exercise in the heat. Therefore, thirst should not be relied on solely as a warning to prevent excessive body water deficits. Athletes should be taught to drink water before, during, and after exercise without waiting for thirst to prompt them; this would reduce the risk of significant dehydration and related heat illness.

For strenuous and endurance activities where large sweat losses are seen, sports drinks are helpful for electrolyte replacement and the prevention of hyponatremia or other electrolyte abnormalities. Several electrolytes, including sodium and potassium, are ingredients of both sports and energy drinks. Sodium content varies from 100 to 200 milligrams (mg) per 240 ml (8 oz), while potassium content ranges from 30 to 90 mg. Too much sodium can cause an excessive feeling of thirst, leading to overdrinking while still overloading the body with salt. Athletes may need as little as 50 mg of sodium per 8 oz. When choosing a beverage, it is important to know its electrolyte content.

Protein, Amino Acids, Vitamins, and Minerals

Many sports and energy drinks contain B vitamins as well as vitamin C. There is no advantage in consuming these vitamins in these drinks as they can be obtained in a well-balanced diet. Protein is an essential part of an athlete's diet. Protein intake should be spread throughout the day. This allows the body opportunity to use the necessary amino acids (AA) throughout the day rather than convert them to fat. Protein ingested shortly before workouts may lead to gastric upset in some individuals. It also may serve as exercise fuel and in small amounts may have a muscle sparing effect preexercise when added to carbohydrates (CHO) in small amounts.

Protein does appear to have an important role in postexercise recovery when combined with carbohydrate. Protein intake provides the necessary amino acids to rebuild muscle broken down during intense exercise and improves muscle hydration. Consumption of CHO + AA (4:1 ratio) after exercising improved postexercise recovery, thus preventing declines in endurance performance in consecutive-day heavy exercise bouts. What research has failed to demonstrate is an actual improvement in exercise performance in endurance athletes following protein or CHO + AA supplementation. Thus, the optimal intake of carbohydrates/protein quantities is likely individual and is influenced by personal tolerance, dietary practices, metabolism, and exercise type as well as duration. Further research is needed to establish optimal carbohydrate/protein types, amounts, and timings of intake with regard to specific types of exercise. Sports drinks containing protein and amino acids can be used for postexercise recovery and rehydration; low-fat milk is another popular option.

Conclusion

Sports drinks have an important but limited role in an athlete's diet. Sports drinks have no significant daily nutritive value in the diet. Their use should be limited to hydration and CHO-E (carbohydrates + electrolytes) supplementation during prolonged, vigorous exercise or CHO-E (±AA) during the immediate postexercise period for rehydration and muscle recovery. Overdrinking can contribute to excessive carbohydrate intake and can contribute to the overweight obesity epidemic in the United States. Sports drinks often contain substances such as vitamins that are better obtained from other dietary sources. The optimal balance of carbohydrates, electrolytes, and water for athletes varies greatly depending on environmental conditions, sweat rates, and the duration and intensity of exercise; therefore, it is difficult to determine the ideal content of a sports drink. Commercially available sports drinks vary greatly in content of carbohydrates, electrolytes, and other substances. An athlete using a sports drink should familiarize himself or herself with the contents of the beverage of his or her choice. It is important to distinguish sports drinks from energy drinks. Energy drinks containing stimulant substances are not recommended for use in children or adolescents and should be avoided in athletes in general. For low to moderate exercise of less than 1-hour duration, water remains the beverage of choice for maintaining an athlete's hydration. Ongoing research continues to add to our knowledge regarding the need for carbohydrates, electrolytes, and protein/amino acids in the athletic population and will likely influence the commercial sports drink industry.

Holly J. Benjamin

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Sports Injuries, Acute

Injuries can be divided into two categories—*acute* and *chronic*. In acute injury, a specific event causes direct trauma to the body and subsequent injury to the tissues involved. Acute injury can vary greatly, from an ankle sprain to a corneal (eye) abrasion and almost everything in between. Acute injury can occur to soft tissue, bone, organs, or nerves. Treatments and duration of healing of acute injuries depend on the severity of trauma and the type of injury. In contrast, chronic injuries are problems that develop over time, often in a predictable manner, and may be the result of repetitive overuse of a region of the body. In sports, the musculoskeletal system, which includes ligaments, tendons, muscles, and bones, represents the primary tissues affected by chronic injury. The treatment of chronic injury also varies based on the type of injury; however, stopping the noxious, repetitive actions is generally required for healing.

Clinical Evaluation

Acute injuries vary in their level of severity. The most common acute injuries involve bruises, sprains, and strains. A mild ankle sprain may require little or no intervention to allow immediate return to play. In contrast, a high-velocity hit to an athlete's abdomen has the potential to cause internal bleeding; a similar blow to the extremities or the spine may cause a fracture. All these can be serious situations that require timely on-site evaluation, stabilization, and transportation to a health care facility. These variations in severity make the clinical evaluation of an acute injury extremely important. Timely assessment is necessary to obtain the most accurate information and exam. Serial exams can reveal clues to a developing serious condition—for example, an intracranial bleed or visceral laceration. Serial exams may also provide reassurance regarding a less worrisome condition that is clinically improving, such as a mild concussion or upper extremity "stinger."

History

The history for an acute injury should be focused and pertinent. The examiner needs to determine when the injury occurred and during what type of movement and what derangements occurred. The timing, character, progression, or improvement of pain and the aggravating or alleviating factors can give helpful clues to the type of injury. Accompanying symptoms of swelling, locking, catching, bruising, bleeding, and neurologic complaints are important for diagnosis. It is also important to know whether the athlete has had any prior injuries, problems, or surgeries, as well as to learn the patient's medical history, for example, chronic illness, medications, and allergies. A thorough, pertinent history can often provide all the clues necessary to make the diagnosis and will at least significantly narrow the differential of diagnosis. The medical history will help determine if the individual has a severe and potentially life-threatening problem that will require more emergent interventions and an escalated level of assistance.

Physical Exam

Physical exams in the setting of acute injury should always follow the American Heart Association guidelines for Basic Life Support. The exam should begin with assessing the athlete's airway, breathing, and circulation (ABCs) and treating problems with these systems before moving to examination of any other body systems or parts, no matter how severe or distracting the injury may appear. Special care and attention needs to be given to any athlete who may have a head or spine injury, and further exam maneuvers need to be done in a way that prevents further injury. For an alert athlete, the exam can focus on the area of injury and first visualize the area of injury, checking for swelling, ecchymosis or bruising, deformity, or skin trauma. Then the area of injury is palpated for tenderness, crepitance, edema (swelling), and, in the case of an abdominal injury, rebound or guarding. More specific exam maneuvers to help better pinpoint the type of injury are then carried out. In the case of a patient with a head injury, who is alert and awake, one would attempt a more complete neurologic exam to include memory, recall, balance, strength, sensation, and coordination. Often, the most accurate physical exam can be obtained immediately following the injury. Serial exams done over the first few minutes to hours after an injury may determine if a condition is deteriorating or improving.

The physical exam may be done at different stages, depending on the nature of the injury and the type of setting in which it is being evaluated. An on-field injury during the course of competition may require a triaged history and focused exam to determine whether the athlete can be safely removed from the field of play. On removal, a more thorough history and physical exam can be performed, either on the sideline or in the locker room. Any athlete, whose injury is deemed to be more severe than can be adequately stabilized and treated on-site should be immediately transported by ambulance to the appropriate health care facility, such as the local emergency room.

Diagnostic Tests

Diagnostic testing may provide helpful clues to the type of injury. Specific tests used and their utility vary. Many injuries require no diagnostic testing at all. Depending on the circumstances, helpful information can be gathered from a variety of diagnostic sources. Computed tomography (CT), magnetic resonance imaging (MRI), and neuropsychological testing may provide information about a head injury. Bone scans, X-rays, ultrasound, compartmental pressure testing, CT scans, and MRI scans can be helpful in musculoskeletal injuries. Laboratory tests, including blood tests and urine tests, as well as some imaging modalities, such as ultrasound or CT scan, can be helpful in chest and abdominal injuries. The type and severity of injury often dictate the need for further diagnostic testing.

Treatment

Treatment of acute injuries varies as widely as the types of acute injuries. Minor scrapes and bruises may require no interventions at all. Intracranial bleeds or abdominal visceral lacerations may require emergency surgeries. Treatment always begins with addressing the basic life support ABCs and when the athlete is stable from a cardiopulmonary standpoint. When the clinician is fully cognizant of any potential spine injuries, further interventions can be done.

A common mnemonic for the treatment of simple, acute musculoskeletal injuries is RICE: *r*est, *i*ce, *c*ompression, and *e*levation. Analgesics may be necessary to control pain in acute injury and rehabilitation settings. Certain injuries may also require casting, bracing, or other form of support or immobilization, and may require nonemergent surgical interventions as well. Physical therapy or other forms of rehabilitation are often used to help an athlete recover from an injury. Occasionally, modalities such as ultrasound, iontophoresis, electrical stimulation, and others can be helpful in getting an injured athlete back to play.

Prevention

The area of injury prevention has become a very important focus of most sports and their governing bodies. It is the reason why protective equipment has been instituted and mandated in many sports. Helmets were introduced into the National Football League and have successfully decreased concussions and head trauma. Mouthguards are now a mainstay in many sports to minimize dental injuries. Contact sports such as lacrosse, field and ice hockey, and football require pads and helmets. People in positions of high risk for contact and injury, such as the catcher in baseball or the goalie in hockey, may be required to wear different safety equipment from others in the same sport at lower risk. Modifications have also been made to playing surfaces in an attempt to minimize injuries, such as the increasingly common synthetic turf in replacement of grass fields or the breakaway bases found on many baseball and softball diamonds. Rules have also been instituted to minimize injuries. For example, head-to-head contact in football is penalized due to safety concerns in allowing this type of collision. Injury prevention will continue to be a focus of all sports, and new equipment, gear, and rules will continue to figure in sports.

Return to Sports

Many acute injuries require little or no intervention and do not prevent athletes from missing any time from their sport. Return to sports is usually dictated by the athletes' ability to recover to the extent that they can function at a level high enough to be productive in their sport and be able to protect themselves from further injury. This means that they must recover full range of motion, sensation, and enough strength to participate without placing themselves or others at higher risk of additional injury. Some acute injuries can be career ending, as many spinal cord–injured athletes have tragically discovered. Other injuries, such as fractures and ligament tears, can have a prolonged recovery period, often with a surgical and postoperative phase with extended rehabilitation, before one can get back to competitive sports. On return, some injuries require further preventive measures, such as bracing or equipment changes, for the athlete to continue to participate.

Benjamin Phipps

See also Ankle Sprain; Contusions (Bruises); Elbow Sprain; Hamstring Strain; Knee Ligament Sprain, Medial and Lateral Collateral Ligaments; Strains, Muscle; Wrist Sprain

Further Readings

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Sports Injuries, Overuse

Injuries can be broadly divided into two categories: chronic and acute. Chronic injuries are problems that develop over time, often in a predictable manner, and may be the result of repetitive overuse of a region of the body.

The human body is remarkably adaptable to physical stresses. Force loads on tissues cause microtrauma and tears of those tissues. The body reacts to this by rebuilding, reinforcing, and strengthening those tissues as it heals them. An increase in the stress on a bone, such as with initiating a new running program, causes a reactive increase in bone matrix, stability, strength, and integrity. Increases in tensile or shear forces of tendons, ligaments, and muscles cause the body to adapt and strengthen these structures as well. When the balance of microtrauma and repair is disrupted, the tissues are unable to heal adequately because tissue breakdown occurs at a rate greater than healing. Over time, the result is development of pathologic tissue that becomes painful and weak. This can occur from excessive loads placed on normal tissues, normal loads applied abnormally to tissues, or normal loads applied to abnormal tissue. Chronic injuries, such as stress fractures, shin splints, exertional compartment syndromes, and tendinopathies, can then result.

Clinical Evaluation

The number of chronic injuries is on the rise in many of our young athletes as we have seen a transition from the multisport athlete to the year-round, single-sport athlete. This has taken away the variety of physical experiences from participation in multiple sports as well as the relative rest that athletes undergo with the change in sports seasons. The clinical evaluation of chronic injuries is imperative to the diagnosis and the treatment of the injury. Chronic, or overuse, injuries represent a significant portion of injuries in many sports. Early and accurate diagnosis can allow for early intervention and breaking of the overuse cycle. The earlier the diagnosis, the more likely the athlete can return to sports in a timely fashion.

History

History is the most important component to helping an athlete with an injury. The history provides the clues to an accurate diagnosis and can give the clues to why the chronic injury developed in the first place. The history should be approached with two outcomes in mind: First, by determining the type of injury present as accurately as possible; and, second, by determining why this injury has occurred. The primary symptom of an overuse injury is pain. It is important to determine when the pain began initially, as well as the descriptive properties of the pain—sharp, dull, ache, burn, and so on. Associated mechanical symptoms such as locking, clicking, or popping should also be noted. Accompanying symptoms of swelling, bruising, and neurovascular problems are also important. The timing of the pain in relation to the athlete's activities may give clues to the extent of the injury. Most chronic injuries follow a typical pain pattern. Initially, they are often noted as a vague ache or discomfort in the few hours to days after a workout. This may evolve in severity and duration of discomfort as the injury progresses, and limitations begin to occur with minimal activity or even at rest. The timing and quality of the discomfort, as well as any change in these factors especially as they relate to specific activities, can give important clues as to the severity of the chronic injury. A history of similar injuries in the past in the same or different locations can aid one in assessing the risk of injury recurrence.

To answer the question "why" an injury developed requires more of an investigative approach. These injuries can have multiple causes. Repetitive overuse may be from training errors, poor mechanics, strength and flexibility imbalances, nutritional deficiencies, poor or inadequate equipment, underlying systemic disease, poor nutrition, or anatomical malalignments and can all lead to chronic tissue injury.

Physical Exam

The physical exam for a chronic injury should initially focuses on the area of pain or concern. Observe for swelling, bruising, deformity, or other obvious abnormality. Gentle palpation can help localize tenderness, the anatomical structures involved, and any accompanying edema. The affected joint or limb should then be put through its usual passive and ultimately active range of motion for evaluation of limitations of movements and painful movements. Resisted testing of isolated muscles, ligaments, and tendons, as well as provocative maneuvers such as the test for shoulder rotator cuff impingement, may further specify the type of injury and the structures involved. A thorough neurovascular exam of the area should be included, and one should always evaluate the joint above and below a possible injury.

Once the diagnosis has been established by history and exam, the examiner should again change the focus of the exam to the question of "why" the injury developed and, more specifically, the intrinsic causes of the chronic injury. These can include anatomical malalignments and subsequent abnormal tension and stresses across structures. There may also be underlying strength or flexibility imbalances of the affected extremity or of the athlete's core musculature. In the case of adolescent or growing athletes, growth alone can cause increased stress on structures incapable of handling the loads placed on them, such as that found in the pain from Osgood-Schlatter disease of the knee or Little League shoulder or elbow. A thorough physical exam for a chronic injury should include a psychological assessment. Fatigue, depression, and psychological stress can all predispose an athlete to injury, causing an overtraining syndrome, which results in physical and psychological inability to exert at an otherwise normal level, much less a highly competitive level.

A dynamic exam reproducing the repetitive movement may be very revealing. This may help discern an abnormal gait, throwing pattern, or technique.

Diagnostic Tests

With chronic injury, diagnostic tests may help confirm the diagnosis suspected based on the history and physical exam. Radiography (X-ray), magnetic resonance imaging (MRI), computed tomography (CT), or bone scan may confirm a suspected stress fracture or bone problem. Musculoskeletal ultrasound or an MRI scan helps evaluate soft tissue injury such as tendinopathies, bursal problems, or ligamentous injury. Video analysis of an athlete's form can be helpful with the dynamic physical exam to better note the details of the motions and more easily discern potential problems. Diagnostic tests are not required to make most chronic injury diagnoses but can be helpful in the cases where there is a doubt.

Treatment

The ultimate treatment for any chronic, overuse injury is stopping the repetitive movements causing the pathology. These injuries require rest. This allows the time for the body to prepare the injured tissue in the cycle of tissue breakdown and healing to adapt to stress. The time required for this to occur is variable; healing can take weeks to months. The rest is relative, only the excessive stressors to the damaged tissue need to be removed. Not all chronic injuries require immobilization or complete removal from all activity. A marathon runner who develops a fibular stress fracture from overtraining may have to discontinue running for several weeks to allow the fracture to heal; however, he or she may be able to maintain his or her cardiovascular fitness and overall endurance by cross-training with a bike or an elliptical trainer or by swimming.

Additional treatments—such as analgesics to control pain, frequent icing, and occasionally topical, oral, or injected steroids—in a chronic injury may be helpful. It is also imperative to correct the underlying problems that led to the injury in the first place. Clinicians should counsel about appropriate training and escalation of activity when applicable.

Prevention

Chronic injuries develop over a long period of time and have underlying causes that are treatable. Therefore, theoretically these injuries are all preventable. Counseling is the most important component of prevention. Preventing overuse injuries requires appropriate warm-up, stretching, and strengthening, as well as a well-rounded training program that includes aerobic, anaerobic, strength, flexibility, agility, and proprioceptive conditioning, all of which help prevent injury. Equally important is knowing the body's capabilities and limitations and allowing adequate rest for the athletes in the preseason and during the season and an adequate period of complete rest annually. For most athletes, it is recommended that they have 2 to 3 months per year of complete rest from the repetitive physical demands of their sport as well as psychological rest. Teaching and coaching proper technique, and appropriate equipment selection cannot be overemphasized. Worn-out or inappropriately sized equipment can be the causative factor in many chronic injuries.

Return to Sports

The athlete is able to return to sports from a chronic injury when the pain has subsided, full range of motion has been regained, and adequate strength has returned. He or she should not return before the underlying cause of his or her injury is addressed, so as not to cause recurrence. Additionally, the return requires a slow progression because resting the affected tissues causes a relative deconditioning. Not allowing appropriate rest for healing to occur will cause recurrence of the initial injury.

Benjamin Phipps

See also Apophysitis; Bursitis; Compartment Syndrome, Anterior; Sports Injuries, Acute; Stress Fractures; Tendinopathy

Further Readings

Griffin LY, Greene, WB, eds. *Essentials of Musculoskeletal Care*. 3rd ed. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2006.

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Sports Injuries, Surgery for

With participation in competitive sports increasing throughout society, the number of sports injuries has increased as well. Most sports injuries are treated nonsurgically, with the use of rest, bracing, physical therapy, and rehabilitation. Today, however, more and more sports injuries are being treated with surgery instead. There are many reasons for this. Over time, our knowledge and experience in sports medicine have evolved. Studies have shown that certain injuries, such as anterior cruciate ligament (ACL) tears, recover better if they are treated surgically. In addition, the invention of newer imaging techniques such as magnetic resonance imaging (MRI) has allowed sports medicine physicians to more precisely diagnose torn structures. Advances in surgical instrumentation and technique have made it possible to surgically repair ligaments, tendons, and cartilage and restore native anatomy without damaging the surrounding tissue. Specifically, the advent of arthroscopy, which allows joint surgery to be performed through tiny incisions using miniature instruments, has been the major surgical innovation in the field of sports medicine.

The rapid increase in the number of sports injuries combined with the growing interest among health care professionals to optimize treatment has led to an explosion in the field of sports medicine. This dedication to perfecting the repair and rehabilitation of sports-related injuries is manifested by two prominent professional sports medicine societies.

Professional Sports Medicine Societies

The American Orthopaedic Society for Sports Medicine (AOSSM) is made up of more than 2,000 orthopedic surgeons who are dedicated to the field of sports medicine. Most members are team physicians whose research has advanced our knowledge of sports injuries. The society was founded in 1972 and often works directly with physical therapists, athletic trainers, and other health professionals interested in sports medicine. Each year, an annual meeting is held in which members meet to discuss and present new ideas and techniques in the field. New recommendations for the treatment of various sports injuries and guidelines for prevention are episodically published by the society.

The American College of Sports Medicine (ACSM) includes all health professionals interested in sports medicine. It has more than 20,000 national and international members, including physicians, surgeons, physical therapists, athletic trainers, and other health professionals who are dedicated to the field of sports medicine. Founded in 1954, the stated purpose of this college is to advance health through science, education, and medicine. Presently, it is headquartered in Indianapolis, Indiana. Each year, the college holds meetings, exhibitions, conferences, and team physician courses that educate and integrate scientific research in exercise science and sports medicine.

Sports Injuries

Each individual sport places distinct stresses on specific joints and muscle groups. Injury rates vary between sports, depending on which structures are at risk. Sports in which the athlete constantly uses his or her arms to throw, shoot, block, or bear weight place high demands on the shoulder, elbow, and wrist. Sports in which the athlete has to move quickly and change direction have a high incidence of lower extremity injuries in the hip, knee, and ankle. Baseball pitchers, swimmers, and tennis players have a high rate of shoulder and elbow injuries. Gymnasts often use their arms to walk or push off and have a high incidence of elbow and wrist injuries. Soccer, basketball, and field hockey athletes need to pivot and often get knee and ankle injuries. Hip injuries are common in kicking sports, such as soccer, and also in dancing. Not surprisingly, foot injuries also occur frequently in dancers.

Most sports injuries do not require surgery. Sprains or strains occur when the muscles or ligaments around the joint are stretched more than they can withstand and suffer tiny tears. These injuries usually heal well over time. Tendons and bursae can become irritated and inflamed, leading to tendinitis or bursitis. These are generally overuse injuries and also heal well over time. These sports injuries are commonly treated with a combination of rest, anti-inflammatory medications (e.g., ibuprofen), and physical therapy aimed at stretching and strengthening the appropriate muscle groups.

Certain injuries do not heal well with rest and rehabilitation and generally require surgery. There are various reasons why some injuries require surgery while others do not. In some cases, the injured structure is located in a joint, where its blood supply and capacity to heal on its own is limited. In others cases, repetitive injuries have stretched the structure too thin and compromised its function. Common sports injuries that require surgery in the shoulder joint include tears of the rotator cuff and labrum and a stretched shoulder capsule resulting from multiple shoulder dislocations. In the knee, ACL tears, meniscal tears, cartilage injuries, and loose bodies are common sports injuries best treated with surgery. In the ankle and elbow, stretched ligaments from repetitive sprains may require repair or reconstruction.

Terminology

An understanding of surgery in sports medicine necessitates a familiarity with the terminology of sports medicine procedures. The following is a list of commonly used terms.

Diagnostic Arthroscopy

Arthroscopy is a minimally invasive surgical technique that uses an arthroscope or small camera inserted into a joint. This will be discussed in more detail below. A diagnostic arthroscopy is that part of the procedure where the surgeon examines the entire joint to look for any sources of pain.

Meniscectomy Versus Meniscus Repair

The *meniscus* is a rubbery cushion inside the knee between the thigh and leg bones. A twisting knee injury can cause a tear in the meniscus. *Meniscectomy* is a common knee arthroscopic surgery in which a small tear in the meniscus is removed. The remainder of the meniscus is left alone. *Meniscectomy* differs from *meniscus repair* in which the tear is not removed but is instead sutured back together.

Repair Versus Reconstruction of Tendons and Ligaments

Repair involves using sutures to tighten an injured structure that has stretched. A repair is usually done for injured ligaments or tendons that have a good capacity to heal but are too lax in their present state. Examples include repair of torn ankle ligaments and patellar tendon repair. *Reconstruction* involves replacing an injured tendon or ligament with a separate structure that can perform the function of the injured structure. Reconstruction is usually performed on injured tendons or ligaments that will not heal properly over time. For example, ACL tears in the knee are usually treated with ACL reconstruction, using a hamstring or patellar tendon to replace the function of the torn ACL.

Loose Body

A free-floating piece of bone or cartilage that has broken away and is moving around a joint is referred to as a *loose body*.

Excision

Excision means removal. For example, a loose body in the knee joint is often treated with excision.

Debridement

Debridement is the cutting out of unstable, frayed pieces of a torn structure. The process of debridement smooths the roughened surfaces of the injured structure so that it does not get caught in places during joint motion. For example, a tear in the labrum of the shoulder or hip is often treated with debridement.

Chondroplasty

Chondroplasty is the smoothing of torn cartilage on the joint surface. Chondroplasty is usually done with the aid of an arthroscopic shaver that levels out the cartilage surface by selectively removing torn and unstable fragments.

Microfracture

In *microfracture,* tiny holes are made in the exposed bone in an area of the joint where the full thickness of the cartilage has been completely damaged. Microfracture uses a miniature awl to perforate the exposed bone in a joint. The goal of microfracture is to stimulate the bone to bleed and form a blood clot over itself. Over time, this blood clot can help form a new type of cartilage, called fibrocartilage, over the area of exposed bone.

Arthroscopy

Arthroscopic surgery uses multiple small incisions (1.5 inches [in.; 1 in. = 2.54 cm]) placed around the joint, called *arthroscopic portals*. A long, thin, pencil-sized rotating video camera called an arthroscope is inserted through one of these portals and into the joint in question. The arthroscope is connected to a monitor, and the image obtained by the camera at the end of the arthroscope appears on the monitor. The joint requiring surgery is filled with a saline solution, and the surgery is done within this solution. The surgeon manipulates the camera with one hand while watching the video image of the joint on the monitor. The surgeon's other hand is used to manipulate the arthroscopic instruments to perform the surgery. Alternatively, a surgical assistant may be used to operate the camera or assist with other instrument manipulation.

Arthroscopy is a minimally invasive alternative to many open surgeries, with advantages including less pain, smaller incisions, and faster rehabilitation. Arthroscopy can be performed on many joints, but it is most commonly used in the knee, shoulder, elbow, hip, and ankle. The types of surgeries that can be performed arthroscopically and the joints in which they can be used are constantly expanding. The requirement for arthroscopic treatment is that the structure in question must be within the joint space and in an area that is accessible using arthroscopic tools. One of the primary indications for arthroscopy is diagnosis. In cases where the diagnosis is unclear after physical exam and imaging, some surgeons may opt to perform an arthroscopy to visualize the injured joint and find the problem.

Arthroscopy is done under sterile conditions in the operating room, as with any other surgery. Many surgeons will use specific positioning devices to allow the limb or joint to be in the ideal position for the procedure. Every arthroscopic procedure begins with a diagnostic arthroscopy, which entails looking around the entire joint to either confirm or determine the causes of the patient's symptoms. The joint surface and the ligaments and cartilage in the joint are thoroughly inspected for tears or abnormalities. The recesses, or pockets, of the joint are checked for fragments of bone or cartilage that may also indicate previous injury.

During the arthroscopy, the surgeon may use a variety of instruments. All instruments are long and thin, with a handle that the surgeon manipulates on one end and the active part of the instrument on the other end. A probe, or a small metal hook, is used to feel and move the cartilage and ligaments seen on the camera. An arthroscopic shaver is a tiny motorized instrument that is used to remove torn and injured tissue inside the joint in a controlled manner. The shaver is connected to a suction device that brings loose and torn tissue into the mouth of the shaver. The tissue is cut by the rotation of the cutter blade. By controlling the amount of suction and varying the types of cutter blades used, the surgeon can control how much tissue is removed. Other small instruments that fit through arthroscopic portals act as scissors, graspers, and cutters, to debride or excise loose pieces of cartilage or tears in the meniscus (knee) or labrum (shoulder and hip).

Commonly performed arthroscopic procedures include debridement, repair, excision, chondroplasty, and microfracture. With arthroscopic debridement, the surgeon can smooth the roughened surfaces that may be causing pain or excise any tissues that may be catching on other joint structures and causing painful symptoms. Ligament and tendon repair and cartilage injuries can also be treated with the aid of arthroscopy. Common arthroscopic procedures done in the shoulder include repair of rotator cuff tears, repair or debridement of labral tears, and tightening of a loose shoulder capsule. Knee problems such as ACL tears, meniscus tears, and cartilage injuries can be treated with meniscus repair or meniscectomy, ACL reconstruction, chondroplasty, or microfracture. Smaller joints such as the elbow, wrist, and ankle often require smaller arthroscopic equipment. Cartilage injuries and loose bodies of the ankle and elbow are often treated with arthroscopy.

Arthroscopic surgery has many benefits. When compared with open surgery, in which the joint is opened through a larger incision and the procedure is done under direct visualization, arthroscopy offers a minimally invasive approach. As noted earlier, the arthroscopic procedures use multiple tiny incisions, which result in a better cosmetic appearance. There is less disruption of the tissues under the skin and in the joint, which causes less scarring and stiffness. The smaller incisions also allow a smaller area of the joint to be exposed to the air, decreasing the risk of infection. Because patients have less pain after arthroscopy, they are able to participate in rehabilitation sooner.

Not all diseases or conditions involving a joint can be treated with arthroscopy. Some surgeries require large exposures of the joint, which arthroscopy cannot offer. Complicated arthroscopic cases may require the surgeon to repair the joint under direct visualization, with an open procedure. This most often happens if a structure that needs to be repaired cannot be reached through the small incision without causing injury to other structures or if there is poor visualization within the joint due to bleeding or other factors.

Most arthroscopic surgeries are done as outpatient cases, meaning that the athlete is able to go home on the day of the surgery. The incisions are small and can often be covered with an adhesive bandage strip. Depending on the type and location of the surgery, the surgeon will make recommendations regarding activity limitations. Some procedures will have strict restrictions on how one can use the operative site (e.g., crutches or lifting restrictions), while others may have no restrictions.

Recovery Time and Rehabilitation

Nearly all athletes who undergo arthroscopic surgery will need physical therapy before they can resume their normal sporting activities. Recovery time varies depending on the nature of the procedure. To return to sports, the patient must demonstrate full range of motion and full strength in the affected joint. The initial goal of physical therapy focuses on *regaining full motion* in the affected joint. After motion is gained and the surgical repair has healed sufficiently, the physical therapists will concentrate on *regaining strength*.

For complicated procedures such as knee ACL reconstructions, shoulder rotator cuff repairs, and shoulder labral repairs, full recovery takes 6 months to 1 year after surgery. For knee meniscal repairs and chondroplasty for cartilage injuries, return to sports generally occurs at about 3 months after surgery. For smaller procedures such as diagnostic arthroscopy, joint debridement, and meniscectomy, return to sports takes about 6 to 8 weeks.

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See also Arthroscopy; Knee Injuries, Surgery for; Principles of Rehabilitation and Physical Therapy; Shoulder Injuries, Surgery for

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Sports Massage Therapist

Sports massage therapy, a specialized branch of traditional massage, is a burgeoning profession worldwide, due to the growing need for it as an adjunct to traditional medical treatment. A 20% increase in demand has been projected over the next decade.

Manual massage (initially called "friction") is performed to improve muscle function and blood circulation via manipulation of the body's soft tissue. Based on the patient's needs and characteristics (e.g., athlete, elderly, pregnant, child), any of several massage treatment techniques or modalities may be used. Each therapist may develop his or her own unique style and may specialize in treating patients with certain diagnoses or conditions.

Sports massage therapy (also known as *manual medicine*) was developed to help athletes recover from an event or workout and to prepare them for top performance. It can be used before, during, and after an event. It is estimated that Americans spend more than $4 billion annually on massage therapy for a variety of reasons, including work, sports, rehabilitation from a motor vehicle accident, and also as a luxurious treat.

In the past few years, referrals for manual medicine have increased significantly and have been integrated into a permanent component of the athlete's training protocol, at all levels—from high school to professional athletic programs. It is a medical preemptive intervention based on the belief that a regimen of massage provides a competitive edge to the athlete. Sports massages are used for athletes as well as for those recovering from an injury. Sports massage is promoted by athletic trainers, team physicians, and sports medicine doctors to assist athletes to prepare their bodies to achieve optimal performance. In a field where a matter of seconds can mean the difference between victory and defeat and where the latest technologies are used to provide an edge over the opponent, sports massage is growing to be an important adjunct.

The reasons to incorporate manual medicine modalities on a regular basis range from aiming to win the gold medal in an Olympic event to assisting in the recovery process of a person with restricted range of motion due to injury. Sports massage is a logical choice, especially if the injury was caused after a sporting event such as a marathon. Preemptive intervention is crucial to prevent injuries. Massage can help promote symmetry and stability of the muscles and joints in the body, thereby avoiding the potential for injury due to abnormal movement or functioning of muscles or fascia.

Massage therapy has become a standard and integral component of athletic training in most sports clinics all over the world. The ultimate goal of a massage therapist is to improve emotional and physical health. The techniques and time spent for each session and the number of sessions may vary based on the physician's massage therapy prescription and goals, as well as the patient's expectations. Massage therapists can specialize in one or more particular techniques based on their interests, community needs, and the market. Currently, there are more than 50 common massage techniques used to promote a healthy mind and body. Each therapist will select a modality that is based on his or her previous experience as well as the needs of the patient.

Some common manual medicine modalities include Swedish massage, deep tissue massage, acupressure, and sports massage. In addition, doctors of osteopathic medicine (DOs) are fully licensed physicians who use various manual medicine techniques, known as *osteopathic manipulative treatment* (OMT), to assist patients toward a return to health. Typically, a massage therapist works along with a physician or athletic team. Most patients seek a massage therapist based on a referral and the specialty of the therapist. There is a wide range in the hours worked per week as well as income earned by massage therapists. One therapist may work 80 hours/week and another in the same area only 15 hours weekly. Income may vary from $30 to $200/hour, based on where the therapist is employed. Variations that may help explain the wide range of salaries include differences in training, which range from 500 to 1,000 hours; knowledge of basic anatomy, physiology, and kinesiology (study of human movement); and practical demonstration of skills. Other factors include interpersonal skills, which affect referrals by other clients, moral character, professionalism, referrals from physicians, attitude, empathy toward the patient, and the ability to engage the patient in a trusting and therapeutic relationship. Prerequisites to become a certified massage therapist include, at the minimum, completion of high school and a desire to assist others. Most massage therapy schools require attendance for at least 6 months and sometimes up to or beyond 12 months, depending on the particular modality specialized in.

In addition to didactic coursework and reading, it is mandatory to obtain experience in the various manual medicine modalities and techniques. It is worth noting that many allopathic medical schools are incorporating several related manual medicine techniques into their curriculum to give their graduates exposure to all forms of manual medicine.

Osteopathic manual therapy is a hands-on form of care. Osteopathic physicians use their hands to diagnose as well as treat injuries and musculoskeletal problems. The first osteopathic medical school was begun in 1892 by Dr. Andrew Taylor Still. Dr. Still was an allopathic physician who was frustrated with aspects of medical care in his time and sought to devise a better way of treating patients.

Most people enjoy getting a massage, and for patients who have been injured during a sporting event and for those who are competitive athletes, seeking the services of a specialist in sports massage therapy may promote speedy recovery, help maintain body shape and symmetry, decrease stiffness and soreness, and reduce the potential for injury.

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See also Complementary Treatment; Manual Medicine

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Sports Socialization

Participation in recreational and competitive sports is widespread in Western cultures. The physical and psychological benefits of physical activity are well known, and most experts agree that everyone should engage in physical activity on a regular basis. Sports participation, including planned physical training and competition, has both positive and negative developmental consequences for participants. Positive benefits from participation include discipline, loyalty, physical development, improved self-esteem, teamwork, sportsmanship, time management, and lifetime patterns of fitness. Conversely, sports participation can also be related to stress, stereotyping, and risk-taking patterns. Sports socialization is the process by which individuals are introduced to sports, taught the physical and behavioral standards, and incorporated into the culture of sports. Parents, coaches, peers, and society all influence the process of socialization into sport.

Process of Socialization

There are numerous theories on the process of sports socialization. Common to most theories is that there is an initial introductory phase where knowledge, cultural norms, and skills of the sports are acquired. Children and adolescents often begin playing the sports that their siblings, friends, and parents find interesting and in which they participate. Depending on individual interests and innate skills, youth self-select the sports in which they would like to continue to participate. Following the introductory phase, individuals further develop their skills, associate with other participants, begin to view themselves as athletes, and are recognized by others as athletes.

Parents have the greatest influence on the sports socialization of their children and adolescents. With the goal of teaching their children positive values and traits, parents introduce their children to sports through game play, television, discussion, and watching as spectators. Parent interaction during sports can also offer opportunities to teach their children lessons regarding desirable morals and social behavior such as sportsmanship, loyalty, teamwork, and determination. It has been shown that children whose parents communicate the importance of sports and foster their training in them find greater enjoyment in sports participation. Surprisingly, parental pressure to succeed has not always been associated with decreased enjoyment.

Sports Goals/Beliefs

Individual motivation and definition of success are personal attributes taught through the socialization process. Two distinct goal orientations have been described: *task* and *ego*. The task-oriented individual describes success in terms of effort and self-improvement, while the ego-oriented individual describes success in terms of comparison with others and demonstrating superiority. Parents and coaches directly influence these two orientations by their actions and their focus on effort, hard work, and collaboration (task) or their focus on winning at all costs, impressing others, and demonstrating superior skills (ego). Similarly, the belief patterns of young athletes can affect their motivation to participate and work hard. Teaching youth that effort should be the focus during participation will foster a pattern of hard work and determination.

Gender Issues in Socialization

The athletic experience is often very different between boys and girls. Competitive males are seen as leaders and deemed role models. Classically male qualities and traits such as intimidation, dominance, insensitivity, and lack of emotional display are often fostered in the realm of sports. These qualities are vastly different from the traits that are often fostered in females during social development (nurturing, sensitivity, and emotionality). Over the past century, women's involvement in competitive sports has become socially accepted and supported. Despite the great strides in equality, female athletes are still expected to possess these dual and often discordant sets of traits.

Burnout and Discontinuation of Sport

A tenet of physical education educators has been to socialize children to sports as a means of beginning a life of physical activity. The idea that involvement in sports as a youth will continue into physical activity as an adult is a common belief; however, it is well documented that individuals tend to discontinue sports participation with increasing age. Research has demonstrated that a pattern of physical activity as a youth can lead to a lifelong engagement in physical activity, but even more consistent is the observation that a pattern of inactivity as a youth leads to inactivity as an adult. Athletes decide to discontinue sports for many reasons, including burnout, changing interests, and changing life situations (work, school, and parenthood).

Burnout among athletes is a phenomenon seen in youth who have been very involved in sports suddenly losing interest in continuing participation and competition. This is seen more often in individual-sport athletes whose lives are consumed by participation in their sports. These athletes often describe a lack of social interaction and a sense of being a one-dimensional individual. Focusing on developing skills outside the sports arena and being involved in more than one sport may decrease the likelihood of burnout and desocialization from sports.

Jason Diehl

See also Burnout in Sports; Mental Health Benefits of Sports and Exercise; Psychology of the Young Athlete; Sports Socialization

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Static Stretching

Static stretching is a form of stretching that slowly elongates the muscle. This can be done actively or passively. In the active form, the person stretches the desired muscle or muscle group to the point of discomfort and holds this for a period of time. The passive form involves a second person (usually a physical therapist or athletic trainer) who assists in stretching the desired muscle or muscle group. Whether active or passive, the goal of the static stretch is to desensitize tension sensors in muscles. Once this occurs, the muscle is able to take on more force before it becomes damaged. A long-standing belief is that this leads to a reduction of injuries as the muscle is more compliant.

Uses

Static stretching has been used as a treatment modality in injury rehabilitation. After a muscle injury, the torn muscle fibers heal in a contracted pattern. Therapists can use static stretching to restore the muscle to its normal length. This helps improve the range of motion in the affected body area. This is usually done in the subacute phase of injury recovery. It can also be used for rehabilitation of certain joint injuries. A common example is stretching the shoulder capsule. Improper mobility following a shoulder injury may result in a frozen shoulder or adhesive capsulitis. The therapist may use static stretches (both active and passive) to improve the shoulder range of motion.

Static stretching has long been used in "warm-up" routines by those engaging in sports activity. The common thought is that loose muscles are less likely to be injured. Multiple studies show that static stretching before an athletic contest may cause small tears in the muscle and make the muscle more prone to injury.

A recent critical review of the literature showed that after a single bout of static stretching, muscle force and torque as well as jump height were diminished. However, when the static stretching was repeated over days to weeks, there seemed to be an increase in muscle force and torque. There was a positive effect of a single bout of static stretching on running economy but not on running speed. Based on these results, it is considered beneficial to perform regular static stretching but not immediately before an athletic contest. Muscles should be warmed by other types of stretching—mainly dynamic stretching.

Examples

An example of a static stretch is the *seated hamstring stretch*. This is performed by sitting on the floor with one leg straight out while the other is bent at the knee with the foot touching the opposite thigh. Then, while keeping the back straight, reach forward with the arms by bending at the waist. A slight stretch should be felt in the hamstring. This is held for 15 to 30 seconds. It may be repeated two to three times.

Another example of a static stretch is the *butterfly stretch*. In the seated position, the knees are bent with the soles of the feet touching. The elbows are used to direct a downward force on the legs. This should cause a slight stretch in the adductor muscles (groin). This is held for 10 to 30 seconds. It may be repeated two to three times.

Richard A. Okragly

See also Exercise Physiologist; Preventing Sports Injuries; Strains, Muscle; Stretching and Warming Up

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Sternal Fracture

Sternal fractures are rare yet potentially serious injuries in athletes. Few sports have a high risk of blunt trauma to the anterior chest wall, the main cause of most sternal fractures. Rapid deceleration injuries fall into this category, often resulting from motor vehicle accidents with the patient restrained. Such injuries are primarily seen in the trauma and emergency department setting, but the sports medicine physician should be aware of suspicious patient complaints associated with chest trauma. Awareness concerning sternal injuries may prevent missed diagnoses, unnecessary and expensive work-ups, and frustration for the athlete.

Sternal and stress fractures have been reported in golfers, weight lifters, and athletes involved in other contact and noncontact sports. Injuries have been reported in repetitive hyperflexion of the torso, such as in exercises that involve sit-up postures. Athletes involved in high-speed sports, high-altitude sports, and high-energy contact sports are theoretically at risk. Other patients at risk are those with osteoporosis or osteopenia, those with severe thoracic kyphosis, and any patient subjected to cardiopulmonary resuscitation.

Anatomy

With direct chest wall trauma, the sternum may fracture at any point. The sternum consists of three parts: (1) the manubrium; (2) the body, or corpus; and (3) the xiphoid process. The xiphoid process forms the distal tip of the sternum. The joint between the manubrium and the body, the manubriosternal joint, forms the sternal angle at the second rib. The manubrium is found at the third and fourth thoracic vertebrae. The superior border is formed by the suprasternal notch. The clavicle and first rib articulate with the manubrium. The sternal head of the sternocleidomastoid muscle inserts at the anterior of the manubrium, along with the sternocostal head of the pectoralis major. The sternohyoid and sternothyroid muscles attach to the posterior surface of the manubrium. The rectus abdominus attaches to the distal xiphoid process.

Symptoms

The patient's history may reveal an abrupt stop or direct chest wall trauma during an athletic event. Initial symptoms of a sternal fracture include acute sternal pain and tenderness with palpation directly over the sternum. There may be soft tissue swelling and bruising but usually not a palpable deformity as most fractures will be nondisplaced. The examining physician should keep in mind the cause of the injury, should influence the acuity of the assessment, and should plan for the patient. For example, sternal fractures related to motor vehicle seat belt injuries are not associated with thoracic vascular injuries or spinal cord injuries and are, therefore, not associated with a significant mortality risk. With more serious traumatic injuries, there may be signs of respiratory compromise, including retractions, tachypnea, and cyanosis. Other conditions associated with direct trauma include rib fractures, pulmonary and cardiac contusion, and intrathoracic vascular trauma, including aortic rupture, cardiac tamponade, flail chest, pneumothorax, hemothorax, spine fractures, spinal cord injuries, diaphragmatic rupture, tracheobronchial rupture, and esophageal rupture.

Diagnosis

The American College of Surgeons provided guidelines in the Advanced Trauma and Life Support algorithms for the management of chest trauma (see the list of recommended readings). Any patient seen initially who has sustained blunt thoracic trauma should have a primary survey for potentially life-threatening conditions, including a complete history and physical exam. Initial studies and labs may include complete blood count, electrolytes, coagulation panel, type and screen, arterial blood gas, and electrocardiogram (EKG). Initial radiographs of the sternum should include a lateral view and a frontal view, with the patient prone and slightly rotated away from the midline. These views have a reported sensitivity of greater than 90%. X-ray (radiographs) may also diagnose other potentially serious injuries, including rib fractures, hemothorax, pneumothorax, and pulmonary contusion.

Radiographs remain the initial gold standard for the evaluation of sternal injury. A frontal view and a lateral view should be obtained, as any displacement usually occurs in the sagittal plane. Any evidence of more serious diagnoses such as arrhythmias, hemodynamic instability, or a widened mediastinum should be evaluated with echocardiography and, possibly, computed tomography scans. The body, or corpus, of the sternum is the area most frequently injured. Ultrasound may be slightly more sensitive in diagnosing fractures, but most experts still consider radiographs to be the first initial choice.

Treatment

After the initial work-up, and after potentially life-threatening injuries have been excluded, further course of treatment involves pain management, usually with oral analgesics. There should be a period of relative rest, especially from contact sports or the offending activity. The patient should be encouraged to perform deep-breathing exercises, as with rib fractures, to prevent atelectasis and pneumonia.

Rehabilitation and Return to Sports

The athlete should be encouraged to maintain cardiovascular fitness if unable to participate in practice or contact drills. Otherwise, the decision to return to play should be made on the basis of whether the athlete can compete painfree in his or her event. The literature on rehabilitation is scanty, but therapy for similar injuries includes early rest and lower extremity exercises, followed by range-of-motion exercises, and eventually chest- and core-strengthening exercises. The time required for complete resolution of pain varies; pain can persist from a few months up to a year or longer.

Christopher McGrew and Edward Dubois Smith

See also Chest and Chest Wall Injuries; Football, Injuries in; Rugby Union, Injuries in

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Sternoclavicular (SC) Joint, Separation of

The *sternoclavicular joint* (SCJ) is located on the anterior chest where the clavicle (collarbone) meets with the sternum (breastbone). Separation of the SCJ is relatively uncommon in athletes and is usually caused by significant trauma to the area resulting from high-velocity injuries, such as those incurred in contact sports or motor vehicle accidents. Separation of the SCJ may be life threatening because of the large blood vessels that run just underneath the clavicle. The practitioner must have a high level of suspicion for these injuries to recognize them when they occur.

Anatomy

The SCJ is a two-sided joint and provides the only true joint connection between the trunk and the upper extremity. The SCJ has an inherent instability, with less than one half of the inner clavicle bone articulating with the upper angle of the sternum. This bony articulation of the joint is inherently unstable. Several ligaments help stabilize the bony anatomy of the joint. These include the weaker anterior and the stronger posterior sternoclavicular and interclavicular ligaments, as well as the costoclavicular ligament. Because of the bony instability, the ligaments are at increased stress and are more susceptible to injury (sprain or disruption) (Figure 1).

Important structures lie in direct proximity to the SCJ. Major vascular structures such as the internal thoracic artery and vein, and the brachiocephalic and subclavian veins travel just underneath the clavicle. Deeper important structures in the SCJ and clavicle include the subclavian and brachiocephalic arteries, the trachea (wind pipe), the esophagus, and the brachial plexus (a major group of nerves that innervate the upper extremity). Injuries to these structures are the main concern following an SCJ separation.

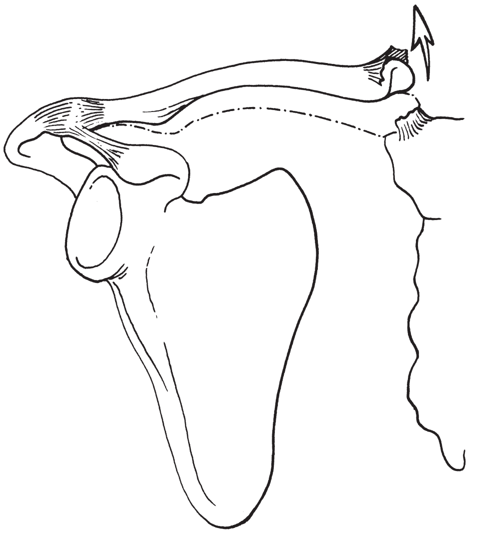

Figure 1 Sternoclavicular Joint Separation

Note: Sternoclavicular joint (SCJ) separation is a sprain of the ligaments of the SCJ, which connects the sternum, or breastbone, with the clavicle (collarbone).

Causes

The most common cause of SCJ separation is vehicular accidents; the second is an injury sustained during participation in sports. This usually involves an athlete falling on one side with an opposing force to the top of the opposite shoulder, such as a pile-up in football or rugby.

The most common mechanism of injury is a blow to the outer aspect of the shoulder, such as a fall on the shoulder. This most commonly levers the medial clavicle (the portion of the clavicle closest to the sternum) anteriorly, increasing the strain on the supporting ligaments and potentially leading to separation of the SCJ. Less commonly, the injury may be caused by a direct blow to the clavicle at its junction with the sternum.

Injuries to the SCJ ligaments fall into three categories. Grades I and II are mild or moderate sprains with minimal displacement of the bony elements of the joint. Grade III injuries are severe and involve complete ligament disruption and significant joint displacement. SCJ separations can occur in both anterior and posterior directions. Anterior SCJ dislocations are more common and less threatening than posterior dislocations. Posterior SCJ dislocations may be life threatening due to the potential damage to vascular structures deep to the SCJ and clavicle. Prompt diagnosis is paramount with posterior dislocations to avoid these serious potential complications.

Diagnosis

Patients generally present with pain and swelling in the area of the SCJ following a history of an acute injury. However, as a result of the significant force needed to cause injury to the SCJ, the patient may have other traumatic injuries that distract both the patient and the examiner from the SCJ injury. The patient may have other life-threatening injuries that warrant immediate attention. A high index of suspicion is required in trauma situations to detect SCJ injuries. Conversely, when an SCJ injury is suspected (especially a posterior dislocation), patient stability should take priority by first assessing the patient's airway, breathing, and circulatory status.

The patient with an injury to the SCJ often has severe pain at the joint that is increased with any movement of the arm, particularly when the shoulders are pressed together by a lateral force. The patient usually supports the injured arm across the trunk with the unaffected arm. The affected shoulder appears to be shortened and thrust forward when compared with the normal shoulder. The head may be tilted toward the side of the dislocated joint. The patient's discomfort increases when he or she is placed in the supine position, at which time the involved shoulder will not lie back flat on the table.

Any injury to the SCJ is difficult to assess with standard X-ray films; however, there are several specialized views, such as the *Heinig view* and *Hobbs axial or serendipity view,* that can make assessment easier. Many experts agree that computed tomography (CT) is the ideal method to image the SCJ. CT is much better at distinguishing separation of the joint from fracture. Additionally, a chest CT with contrast material can also assess the major important structures that run underneath the SCJ.

Based on the degree of injury to the SCJ, injuries are classified as Grades I, II, and III. With Grade I sprains, there is stretching and partial tearing of the SC ligaments. The costoclavicular ligament is usually not involved. With Grade II SC sprains, there is complete tear of the SC ligaments and the SC capsule. The costoclavicular ligament may be stretched or have partial tearing. Instability of the SCJ is present with possible subluxation. Grade III sprains involve a dislocation of the SCJ either anteriorly or posteriorly, with complete tearing of the SC and costoclavicular ligaments.

Treatment

Treatment of SCJ separation depends on the severity of injury. Mild ligamentous sprains (Grade I) are stable and are always treated conservatively. Ice is recommended initially to reduce the inflammation. The involved extremity is immobilized in a sling for 1 to 2 weeks, followed by early range-of-motion exercises.

Grade II sprains differ from Grade I sprains in that a joint subluxation has occurred. The capsule, intraarticular disk, and costoclavicular ligaments may be partially disrupted. The sprained SCJ is stable and can be painful. These injuries can usually be reduced satisfactorily by drawing the shoulders backward as if reducing and holding a fracture of the clavicle. A clavicle strap can be used to hold the reduction. A sling and swath is used to hold up the shoulder and to prevent motion of the arm. The patient should be protected from further injury for 4 to 6 weeks.

SCJ dislocations (Grade III sprain) are the most severe in the continuum of SCJ injuries. This is considered an unstable injury, and if posterior dislocation occurs, the underlying structures can become compressed and may be life threatening. The treatment of choice is a closed reduction restoring the normal bony anatomy of the joint. Techniques for this type of reduction depend on the type of dislocation and should be performed as quickly as possible. If an anterior dislocation has occurred, the patient should be informed that these injuries have a high incidence of recurrent instability but that the symptoms rarely limit normal activities. This avoids misunderstandings later in the treatment course.

Return to Sports

The return-to-play decision must be made with the athlete's well-being as the single most important deciding factor. Consideration should be given to the athlete's ability to move the arm through a full range of motion. Strength is vitally important so that athletes can both protect themselves and be effective in their sport. Special custom padding (or shoulder pads) can be worn to protect the top of the shoulder or the front of the sternum. Even after return to play, it is not unusual for the athlete to experience periods of discomfort for up to several months.

Chad Asplund and James Borchers

See also Acromioclavicular (AC) Joint, Separation of; Football, Injuries in; Musculoskeletal Tests, Shoulder; Rugby Union, Injuries in; Shoulder Dislocation; Shoulder Injuries

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Stimulants

Athletes have been known to use stimulants in and out of competition. Most stimulants are banned by the World Anti-Doping Agency (WADA), but a few stimulants, such as caffeine, are monitored and allowed up to certain levels in the urine.

Stimulants are substances that activate the sympathetic nervous system. This is the part of human physiology that gives us the “fright, fight, or flight” response. The sympathetic nervous system is what gives a person the burst of energy, power, and alertness to deal effectively with a threat or stressor. In the wild, it is the response we would have if we were threatened by a hungry predator. Similarly, it is the response we feel with the stress of public speaking or the excitement of competition. Physiologic effects include increased heart and breathing rates, dilation of the pupils, and sweating. A person would also feel a burst of energy, a heightened state of alertness, and possibly improved concentration or even euphoria. Stimulation of the sympathetic nervous system also inhibits gastric motility (activity in the intestine), stimulates piloerection (goose bumps, or hair standing on end), and liberates nutrients in the body for muscle action.

There are many different types of stimulants, and they come in different forms and strengths. Amphetamines, nicotine, and even cocaine all fall into the category of stimulants. The most commonly used stimulant is caffeine. This is found in different concentrations in *coffee,* tea, soft drinks, and energy drinks. A typical cup of coffee (8 ounces [oz; 1 oz = 28.34 grams]) generally has approximately 100 milligrams (mg) of caffeine (although larger sizes of stronger brewed coffee may have up to 150 mg). Tea usually has around 50 mg per cup (8 oz), and soft drinks have between 50 and 65 mg per 12-oz serving. Energy drinks may have up to 150 mg of caffeine per serving. Soft drinks are required by the Food and Drug Administration (FDA) to keep caffeine levels below 65 mg per 12-oz serving. This rule does not apply to energy drinks, and they often come in serving sizes larger than 12 oz. Some energy drinks containing more than 300 mg of caffeine have been marketed. In addition, energy drinks or dietary supplements may also contain other ingredients that have benign- or exotic-sounding names but still have stimulant properties. Common examples of these lesser-known stimulants include guarana, ma huang, and yohimbe.

Caffeine is also available in a concentrated tablet form, and it is used to increase alertness, energy, and mood. Stimulants such as caffeine also have an appetite-suppressive effect, and they have been used to aid in weight loss. Stimulants do have a performance-enhancing effect in some sports. They have been used by athletes to increase the utilization of body fat for energy and to decrease perceived effort, particularly during intense endurance training.

Caffeine in particular has an interesting history when it comes to sports. In the 1980s and 1990s, caffeine was a banned substance, and several athletes were banned for positive tests. Before January 2004, caffeine levels over 12 micrograms/milliliter (μg/ml) in the urine were unacceptable. Since that time, caffeine has been removed from the list of banned substances by WADA. It is still considered a restricted substance with the National Collegiate Athletic Association (NCAA; the governing body for college sports). If the concentration of caffeine in the urine exceeds 15 μg/ml, the athlete can be disqualified. Urine concentration levels vary per individual, but, in general, to exceed this level, an athlete would have to ingest around 500 mg of caffeine 2 to 3 hours prior to the test.

Cathine and ephedrine are still restricted by WADA. Cathine is a stimulant related to amphetamines and is found in the khat plant. It is a Schedule IV drug in the United States (prescription medication) and is used as an appetite suppressant and decongestant. Cathine is prohibited by WADA when its concentration in urine exceeds 5 μg/ml. Ephedrine is commonly found in over-the-counter cold remedies, antihistamine products, energy drinks, and dietary supplements. Ephedrine and methylephedrine are prohibited by WADA when their concentration in urine exceeds 10 μg/ml. Athletes are responsible for knowing all the contents, effects, and consequences of any product that they ingest, and they are responsible for the product's effect on their test results.

The stimulant epinephrine (adrenaline) is included with some local injectable or transdermal anesthetic agents such as lidocaine or novocaine. Use of small amounts of epinephrine in this form is not prohibited.

The stimulants amphetamine and dextroamphetamine have been used as a treatment for attention deficit disorder (ADD). Increase in the concentration of these medications makes them beneficial.

Anyone who takes stimulants should be aware of their potential side effects. Because there is an increase in heart rate and blood pressure, heart attack or stroke is possible. They can temporarily raise blood sugar levels in patients with diabetes and contribute to insomnia. Overdose or long-term abuse of stimulants can cause paranoia, depression, and psychosis. Stimulants such as caffeine can cause stomach cramps, dizziness, or tremor. Athletes ingesting stimulants such as caffeine must take this into account before training or competing, particularly in endurance events or events that require a steady hand such as archery. Possession of certain outlawed stimulants such as cocaine, ephedra, or MDMA (3,4-methylenedioxy-*N*-methamphetamine; found, among other chemicals, in the recreational drug of abuse ecstasy) also has legal consequences.

Michael O'Brien

See also Doping and Performance Enhancement: A New Definition; Performance Enhancement, Doping, Therapeutic Use Exemptions

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NIDA for Teens: http://teens.drugabuse.gov

UpToDate: http://www.uptodate.com/patients

World Anti-Doping Agency (WADA): http://www.wada-ama.org

Strains, Muscle

Strains often occur in muscles that move two joints, for example, the hamstring muscles that flex the knee and extend the hip joint. These are caused by overstretching or eccentric overload and are located in the muscle-tendon junction. These ruptures occur as a result of the intrinsic force generated in the athlete's muscles, often in the change between eccentric and concentric traction, which is common in high-speed sports and accounts for 10% to 40% of injuries in soccer, Australian Rules football, and American football. When the demand made on a muscle exceeds its innate strength, rupture may occur—for example, in overload during eccentric muscle traction.

Muscle and tendon strains are caused by an abnormally high tensile force that causes rupturing of the tissue and subsequent hemorrhage and swelling. The likelihood of injury depends on the magnitude of the force acting and the structure's cross-sectional area. The greater the cross-sectional area of muscle, the greater its strength, meaning the more force it can produce and the more force that is translated to the attached tendon. The muscle portion of the musculotendinous unit usually ruptures first because tendons, by virtue of their collagenous composition, are about twice as strong as the muscles to which they attach. Muscle strains are rated according to the extent to which associated motion is impaired.

Strains can be classified by the degree of rupture: First- and second-degree strains are partial ruptures, and third-degree strains are complete ruptures or disruptions. A first-degree, or mild, strain describes an overstretching of the muscle with a rupture of less than 5% of the muscle fibers. A second-degree moderate strain involves a more significant but less than complete tear of the muscle. The pain will be worsened by contracting the muscle. A third-degree, or severe, strain involves complete disruption of the muscle.

Abdominal Muscle Strains

Muscular strains are caused by direct trauma, sudden twisting or extension of the spine, or the Valsalva maneuver during weight lifting. The rectus abdominis is the most commonly affected muscle. Pain and spasm in the injured muscle may evoke muscle pain, and any attempt to do a sit-up, straight leg raise, or hyperextension of the back significantly increases muscle pain.

Elbow Strains

Injury of the elbow flexors will result in point tenderness on the anterior distal arm. Pain increases with resisted elbow flexion. With a triceps strain, resisted elbow extension produces discomfort. Strains to the common wrist flexor group result in pain on resisted wrist flexion, whereas strains to the wrist extensors produce pain with wrist extension.

Wrist and Finger Strains

In the hand, muscle strains involving the finger flexors or extensors tend to be more serious. These injuries may involve avulsing the tendon from the bone.

Jersey finger: A jersey finger typically occurs when an individual grips an opponent who simultaneously twists and turns to get away. The ring finger is more commonly involved.

Mallet finger: Mallet finger occurs when an object hits the end of the finger while the extensor tendon is taut, such as when catching a ball.

Cervical Strains

Usually, the sternocleidomastoid or upper trapezius is involved. Strains typically occur at the extremes of motion or in association with a strenuous muscle contraction, an external force, or weakness caused by poor posture.

Pectoralis Major Muscle Strains

The strain may be caused by sudden violent deceleration movements. The frequent underlying reason is abuse of anabolic steroid. The mechanism for this strain may be inappropriate muscle hypertrophy and an increase in power without a concomitant increase in tendon size.

Strains of the Hip and Thigh

Strains of the hip and thigh are encountered in many sports or exercise activities with repetitive motions. Signs and symptoms include a local sharp pain, edema, weakness, and difficulties to contract against resistance.

Hamstring Strain

Ballistic action or a violent stretch may cause this injury. Risk factors are poor flexibility and posture, muscle imbalance, improper preparation, muscle fatigue, lack of neuromuscular control, previous injury, overuse, and improper training technique.

Chronic Muscle Strains

A chronic muscle injury can be defined as an injury that is characterized by disruption of muscle fibers that results in muscle dysfunction. Chronic muscle strain injuries account for 10% to 20% of all muscle strain injuries. These injuries are frequently not recognized and can cause considerable disability, particularly in athletes without any preparedness. Aggressive rehabilitation aiming to restore muscle strength, flexibility, and neuromuscular control is a treatment of choice. Deep transverse friction, stretching of the fibrotic muscle area, and conditioning of the affected muscle with concentric isotonic or isokinetic exercises to eccentric exercises is recommended. Muscle endurance exercises must also be added early in the program.

Repetitive Strain Injuries

These injuries develop following repetitive or sustained submaximal work of the soft tissue structures (i.e., muscles, tendons, ligaments, and nerves). The number of repetitions, duration and intensity of the exercise, and ergonomics of the activity contribute to this damage. Management should include careful review of the exercise program and modification of the inciting repetitive loads. Surgery is reserved for those with no response to conservative therapy.

A history of muscle strain and muscle weakness is a risk factor for muscle strains. Muscle-strengthening programs with an eccentric loading to specific muscle groups create a risk for injuries. Injury-prone athletes should be addressed with appropriate interventions to reduce the incidence of muscle strains.

Şirin Topçu

See also Calf Strain; Gluteal Strain; Groin Strain; Hamstring Strain; Hip Flexor Strain

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Strength Training for the Female Athlete

Since the inception of Title IX of the Educational Amendments of 1972, female participation in sports activities has increased dramatically. The desire to become stronger and thereby improve performance has also risen. Women who use strength training to improve performance range from high school athletes, to the postmenopausal age-group, to those pursuing strength training sports such as bodybuilding and power lifting. Strength training is defined as the use of barbells, dumbbells, machines, and other resistive methods to increase one's ability to exert or resist a force. *Strength training* and *resistance training* are often used synonymously. Strength training has many known benefits, including cardiovascular fitness, good body composition, better bone health, lowering of cholesterol, and better mental health. The female athlete may also benefit from the improved attitude and body image that strength training often provides.

The Gender Difference

It is well documented that the response of muscle tissue to strength training by both males and females is similar. Anatomic differences, however, influence the absolute changes females are able to make in their physique with strength training. Males have a longer growth period than females, resulting in the average adult man being larger than the average adult woman. For women, this results in a lower center of gravity and better balance compared with men. Men also weigh about 11 kilograms (kg) more than women but have about 11% less fat than women. Women have narrower shoulders and wider hips. Females have less muscle mass compared with an equally trained male. This accounts for a male's ability to jump higher, run faster, and lift heavier weights compared with an equally trained female. Hormonal differences (lower levels of testosterone) in females will prevent them from becoming too bulky or large. These differences still allow males and females to strength train the same way. However, a training program should be tailored to the individual.

Nutritional Aspects

While males and females may strength train the same way, their nutritional needs are different. Males tend to use glycogen (stored glucose) for energy during exercise, whereas females tend to use more intramuscular (within the muscle) fat. The popular idea of a higher–carbohydrate, low-fat diet for a female who is strength training may not yield the strength gains that a diet higher in healthy fats would. The common practice of females withholding calories to lose weight will further impair the benefits of strength training. The diet of a strength-training female athlete should still consist of carbohydrates, protein, and fat. Carbohydrates should have a low glycemic index (produce small fluctuations in blood glucose levels) and include fruits, vegetables, brown rice, enriched whole-grain breads, whole-grain prepared cereals, rolled oats, beans, legumes, and sweet potatoes. Protein consumption should be 1.4 to 1.8 grams (g)/kg daily. The optimal anabolic (muscle growth) environment would be one of several portions of high-quality, rapidly digested protein with carbohydrate throughout the course of a day. Appropriate sources of protein would include lean pork and beef, poultry, fish, eggs, and low-fat dairy products. These are also excellent sources of micronutrients such as vitamin B_{12} and D, thiamine, riboflavin, calcium, phosphorus, iron, and zinc. Vegetarianism limits the amount of protein in the diet, and these females are at risk for iron-deficiency anemia.

Healthy fat intake is often a difficult concept for females using strength training to improve their physique. Fat has more readily available energy per gram than any other food source. It is necessary for the production of endogenous (made by the body) hormones such as estrogen and testosterone. When fat is withheld from the diet, menstrual disturbances and compromises to bone health may occur. Healthy fat sources include nuts, seeds, nut butters, fatty fish (salmon and trout), fish oil supplements, flaxseed oil, sunflower oil, canola oil, avocados, and egg yolks.

The Preadolescent and Adolescent Female

Controversy has surrounded strength training by children. For many years, children and adolescents have been discouraged from strength training because of concerns about damage to the growth plate from shear forces. However, it is now accepted that strength training is a viable method of improving performance and decreasing risk of injury in young athletes.

The age at which strength training should begin has not been determined. It has been found though that strength training of sufficient intensity and duration can enhance strength beyond what is considered normal for a particular age. A child or adolescent is likely ready for strength training when he or she is emotionally mature, follows instructions, and understands the risks and benefits. The American College of Sports Medicine recommends that children strength train two to three times weekly on nonconsecutive days. By allowing for adequate recovery time, overuse injuries should be prevented. In this population of athletes, greater strength gains have been found in moderate-weight, higher-repetition exercises than vice versa.

The mode of training can be a challenge for this population. Adult-sized machines may be too large, and child-sized weight machines are expensive and difficult to find. Free weights are a good option, because they are readily available and inexpensive. It is imperative that proper supervision is provided. Barbells are often preferred over dumbbells as they promote better form. In children and adolescents, much of the emphasis during strength training should be on core (low back, abdomen, and hips) strength.

A strength program should consider the goals, level of experience, and sports activity both current and past. Training should not take up more than 20 hours a week. A session should include warm-up (5–10 minutes of aerobic activity and stretching), aerobic activity, and then resistance training. One to three sets of 13 to 15 repetitions of many different exercises would be ideal.

The Older Female

The older female strength trains for slightly different reasons from younger females. The cardiovascular, bone, and cholesterol benefits are still attained. The difference is that strength training in the older female aims at increasing muscle mass and avoiding disability. In large part, the goal of strength training in this population is to maintain independence. A fall inducing a hip fracture is most serious for older women, due to the resultant permanent alterations in activity and long hospitals stays. Prevention of hip fracture has an obviously huge impact on the feasibility of independence in older women. The normal process of aging leads to a tremendous amount of atrophy and weakness that can be avoided with strength training. High-intensity training has been found to be more beneficial than low-intensity training in the older female.

Conclusion

Strength training is an excellent way to promote long-term health and increase muscle mass for females. While males and females have many anatomical differences, the effect or strength training on muscle tissue is quite similar. Special dietary considerations with adequate amounts of fat, protein, and carbohydrate should be included. The continued increase of females in athletics will most likely coincide with a continued increase in strength training by females. As noted earlier, strength training programs should be tailored to each individual. The goals of the female should dictate the choice of exercises, intensity, repetitions, and rest period combinations. This individual approach will likely result in long-term benefits from strength training.

Michelle Wilson and Jeffrey Guy

See also Core Strength; Female Athlete; Resistance Training; Running a Strength Training and Conditioning Facility

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Strength Training for the Young Athlete

Strength training refers to a specialized method of physical conditioning that involves the progressive use of a wide range of resistive loads and a variety of training modalities designed to enhance or maintain muscular fitness. Despite the traditional concern that strength training is potentially injurious to the developing musculoskeletal system of children and adolescents, research studies and clinical observations indicate that participation in strength-building activities can be safe, effective, and enjoyable for children and adolescents. Because muscular fitness is required for success in most sports, a growing number of young athletes now strength train in school-based programs and sports training centers.

Potential Benefits of Youth Strength Training

Well-designed youth strength training programs may offer observable health and fitness value to children and adolescents. In addition to increasing muscular strength, muscular power, and local muscular endurance, regular participation in a youth strength training program has the potential to positively influence aerobic fitness, body composition, bone mineral density, and selected psychological measures. Moreover, carefully planned youth strength training programs may enhance motor performance skills, such as jumping and sprinting, and improve sports performance.

Another important benefit of youth strength training is its ability to improve the preparedness of young athletes for the demands of sports practice and competition. A growing number of aspiring young athletes are ill-prepared for the demands of sports training due to their sedentary lifestyle. While factors such as growth, improper footwear, and hard playing surfaces have been implicated as risk factors for overuse injuries in young athletes, the background physical activity level of boys and girls must also be considered. A significant number of injuries sustained by youth while playing sports could be prevented if more emphasis was placed on enhancing musculoskeletal strength and improving skill-related fitness abilities such as agility, balance, and coordination prior to sports participation. Preseason conditioning programs that included strength training have resulted in decreased injury rates in adolescent athletes, and it seems likely that this type of conditioning could offer a similar protective effect in children.

Risks and Concerns

The belief that strength training is unsafe for young athletes is not consistent with the needs of children and adolescents and the documented risks associated with this type of training. While the unsupervised and improper use of strength training equipment may be injurious, there is no scientific evidence to suggest that the risks and concerns associated with supervised and sensibly progressed youth strength training programs are greater than those arising from other sports and recreational activities in which children and adolescents regularly participate.

A long-established concern associated with youth strength training involves the potential for injury to the epiphyseal plate or growth cartilage. Although young athletes are susceptible to epiphyseal plate fractures, this type of injury has not been reported in any prospective youth strength training study. Furthermore, strength training will not negatively affect growth or maturation during childhood and adolescence. It appears that the greatest concern for young athletes who strength train is the risk of overuse soft tissue injuries, particularly to the lower back.

To reduce the risk of injury, youth strength training programs must be well designed and supervised by qualified professionals who should be careful to match the strength training program to the needs, interests, and abilities of each child. This is particularly important for untrained youth, who often overestimate their physical abilities and may not be aware of the inherent risks associated with strength training equipment. Special care is also needed when children and adolescents use exercise equipment at home, where they may be more likely to strength train without supervision or engage in unsafe behavior. Professionals must be aware of the inherent risk associated with strength training and should attempt to decrease this risk by following established training guidelines. Youth should not strength train on their own without guidance from qualified professionals.

Program Design Considerations

Although there is no minimum age for participating in a youth strength training program, children should have the emotional maturity to accept and follow directions and should appreciate the benefits and concerns associated with this mode of exercise. If a child is ready for participation in some type of sports activity (generally at age 7 or 8), then he or she may be ready to strength train. It is important that young athletes begin strength training at a level that is commensurate with their physical and cognitive abilities. Prescribing a program that exceeds a child's capabilities not only increases the risk of injury but may also undermine the enjoyment of the strength training experience. While the long-term goals of youth and adult strength training programs may be the same, the focus of youth programs should be on skill development and having fun.

A variety of strength training programs have been developed and recommended for children and adolescents. Various combination sets and repetitions and different types of equipment, including weight machines, free weights (barbells and dumbbells), medicine balls, elastic tubing, and body weight exercises, have proven to be safe and effective. Factors such as cost, proper fit, weight stack increments, and quality of instruction should be considered when evaluating strength training equipment for youth. Since most children are too small for adult-sized weight machines, child-size weight machines or other less expensive types of equipment can be used. If equipment is not available, a circuit of body weight exercises can be developed.

In general, it has been recommended that children and adolescents strength train 2 or 3 days per week on nonconsecutive days and perform one to three sets of 6 to 15 repetitions on 8 to 12 exercises that focus on the upper body, lower body, and midsection. It is reasonable to begin strength training with one or two sets of 10 to 15 repetitions with a light to moderate weight of basic exercises. As youths gain confidence in their abilities to perform these exercises with proper technique, heavier weights and more advanced multijoint movements can be incorporated into the strength training program. However, when learning any new exercise, youths must first learn how to perform each exercise correctly with a light weight and then gradually increase the training weight without compromising on exercise technique. This approach will not only allow for positive changes in muscle function but also provide an opportunity for participants to gain confidence in their abilities to perform strength exercise.

Over time, continual gains can be made by changing the exercise choice, exercise order, training weight, number of repetitions, number of sets, or training frequency. On average, a 5% to 10% increase in training weight is appropriate for most exercises. Since training-induced strength gains are impermanent and tend to regress toward the pretraining values once the training stops, program variation is needed to optimize training adaptations, reduce boredom, and promote exercise adherence. Planned variation in the strength training program can also help prevent training plateaus, which are not uncommon after the first 2 to 3 months of strength training.

Basic education on proper exercise technique, fitness training, and realistic outcomes should be part of all youth strength training programs. Professionals who work with youth need to listen to each child's concerns and monitor progress. Some youths with poor levels of fitness may not be able to tolerate the same amount of exercise as some of their peers in the same training program. This is where the art and science of developing a strength training program come into play, because the principles of training specificity and progressive overload need to be balanced with individual needs, goals, and abilities.

Youth strength training requires qualified supervision, appropriate overload, gradual progression, and adequate recovery between exercise sessions. When designing strength training programs for young athletes, the goal of the program should not be limited to increasing muscular fitness. Teaching youth about their bodies, promoting safe training procedures, and providing a stimulating program that gives participants a more positive attitude toward strength training and physical activity are equally important. Strength training should be recommended to young athletes as part of a total fitness program that should include a variety of physical activities and sports pursuits.

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See also Conditioning; Resistance Training; Young Athlete

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Stress Fractures

Stress fractures are overuse injuries of bones. They are common in both competitive and recreational athletes who participate in repetitive activities such as running, jumping, marching, and skating. Stress fractures were first described as "march fractures" in military recruits who had recently increased their level of impact activities. These injuries are true overuse injuries that result from an accumulation of microdamage during exercise, exceeding the body's natural ability to repair this damage. This accumulation of microdamage can cause pain, weaken the bone, and lead to stress fracture. The majority (95%) of stress fractures occur in the lower extremity and most commonly involve the tibia, fibula, metatarsals, or navicular bone. Treatment of stress fractures depends on both the site and the severity of injury.

Etiology

During repetitive loading cycles, bones are exposed to mechanical stresses that can lead to microdamage or microscopic cracks. Fortunately, when given adequate time for recovery, the body has the ability to heal and further strengthen bones through remodeling and repair mechanisms. These healing mechanisms depend on many factors, including hormonal, nutritional, and genetic factors. Unfortunately, under certain conditions, such as starting a new training program or increasing the volume of a current program, the damage to bones is enough to overwhelm the body's ability to repair. In these circumstances, there can be an accumulation of cracks and inflammation that leaves the bones at risk of fatiguing and fracturing. This fatigue failure event is termed the stress fracture. The severity of the injury is determined by the location of the stress fracture and the extent to which the fracture propagates across the involved bone.

Diagnosis

History and physical examination are fundamental for the practitioner in making the diagnosis promptly. Patients typically present with an insidious onset of localized pain at or around the site of the injury. Initially, the pain from a stress fracture is only experienced during strenuous activities such as running and jumping. However, as the injury worsens, pain may be present during activities of daily living, such as walking or even sitting. Physical examination classically reveals a focal area of bony tenderness at the site of the fracture. Soreness in the surrounding joint and muscle is common, and in severe cases, palpable changes to the bone at the site of injury may be present.

Multiple modalities of imaging are routinely used in diagnosing stress fractures. Plain radiography (X-rays) is the most commonly used test to diagnose a stress fracture, but within the first few weeks of injury, X-rays often will not reveal the presence of the fracture. Bone scans, a nuclear-enhanced image modality, have classically been used in the evaluation of stress fracture and have proven to be very sensitive. In recent years, magnetic resonance imaging (MRI) has become the diagnostic test of choice for many physicians because of its superior availability, shorter exam time, earlier fracture detection, and image quality and because it can show damage to other structures such as muscles or ligaments, which conventional X-rays do not.

Classification

Stress fractures can be classified as high- or low-risk injuries based on their location. This classification allows a practitioner to quickly implement treatment for each stress fracture. Low-risk sites include the medial tibias (shin), femoral shafts (thigh), first four metatarsals (foot), and ribs. These locations tend to heal and have a lower likelihood of recurrence, progression to nonunion (not healing), or completion (worsening) of the fracture. Conversely, high-risk stress fracture sites have a higher complication rate and require prolonged recovery or surgery before the athlete can return to participation. Common high-risk sites include the femoral neck (hip), anterior tibia, medial malleolus (ankle), patella (kneecap), navicular (ankle), sesamoids (foot), and proximal fifth metatarsal.

Treatment

The treatment of stress fractures will vary with the location of the injury, severity of injury, and treatment goals. Low-risk stress fractures generally heal faster and with a lower incidence of poor outcomes than high-risk stress fractures. Depending on the particular injury, treatment may include discontinuation of the precipitating activity only, discontinuing all training activities, or, for more serious injuries, crutches or surgery. For minor injuries, healing may take as little as 3 to 6 weeks of avoiding the precipitating activity with continued cross-training followed by a gradual return to the pre-injury level of participation. More severe injuries often take 2 to 3 months or more of aggressive treatment. While treating the stress fracture, it is important to evaluate and modify risk factors that may predispose the athlete to future injuries, including anatomic abnormalities, biomechanical forces, hormonal imbalances, and nutritional deficiencies. Returning to play after a stress fracture usually is granted once the athlete is painfree with activities, is nontender to palpation, and, for high-risk sites, shows evidence of healing on imaging.

Jason Diehl

See also Femoral Neck Stress Fracture; Foot Stress Fracture; Groin Strain; Hip Stress Fracture; Olecranon Stress Injury; Pelvic Stress Fracture; Rib Stress Fracture; Spondylolysis and Spondylolisthesis; Stress Fractures; Tibia and Fibula Stress Fractures

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Stretching and Warming Up

From time immemorial, stretching and warm-ups have been a part of athletic training and competition. These routines are purported to improve performance and to reduce injury and postexercise soreness. Perhaps surprisingly, although research supports the position that warming up is critical, the evidence is tenuous that stretching itself is beneficial. In fact, some stretching evidently predisposes to injury and reduces performance. A long-term program of stretching after exercise probably reduces injuries or postexercise soreness, but this is also controversial. Thus, there is a major shift occurring in the practice of stretching. This entry describes what, why, and how we should stretch and then reviews what role stretching should play in warm-ups.

What to Stretch

Stretching affects the ligaments that provide joint stability, the tendons that connect muscle to bone, and/or the muscle that produces power. Stretching has been discovered to induce changes in the nervous system as well. Ligament stretching is generally not desirable, as described below. Tendon stretching is difficult and of limited benefit. It is in the muscle that most stretching occurs.

Muscles have elastic properties, which means that if stretched, they will tend to return to their original length. They also have viscous and plastic properties, which means that if stretched for long enough (repeatedly for about 30 seconds), they tend to remain lengthened and only slowly return to their original length. The viscoelastic changes that occur with stretching have been considered the reason why the muscle lengthens. But some of the changes turn out to be the result of decreased pain thresholds or decreased muscle strength, which have as many detrimental effects as good ones.

Why Stretch?

The traditional reasons to stretch are to increase range of motion (ROM) around a joint, to increase flexibility of the muscle, and to warm up the body in preparation for intense exercise. We will deal with each of these putative attributes in turn.

Range of Motion

ROM is the arc through which a joint can move. Some sports such as gymnastics require large ROM. But simply increasing ROM around a joint is not necessarily useful. An increased range must be accompanied by sufficient muscle strength to protect the ligaments, tendons, and muscles from injury. This muscle strength is also necessary to allow use of the body in that new ROM, or it has little purpose. For instance, the ability of a backstroke swimmer to externally rotate the arm so that the hand is above and behind the head is only useful if the ROM is also accompanied by strength and power of the muscles to produce faster swimming. Much of the stretching we have traditionally done produces increased ROM by stretching the ligaments, which may already be too loose, and actually decreases the power of the muscles for a short time.

For example, a stretching exercise sometimes used by swimmers to increase shoulder external rotation is having a partner pull the arms back as far as possible. The anterior ligaments of the shoulder that limit this motion are rarely tight because most swimming motions stretch them daily. Stretching these ligaments may adversely affect joint stability. Tightness in the front of the shoulder arises when muscles such as the pectoralis get short. If we are to increase ROM, it must be done under control, preferably with the athlete's own muscles, so that strength and power increase in coordination with flexibility of all the related muscles.

Ligaments hold joints in precise positions throughout the ROM, and usually they are best left alone to do what they were marvelously designed to do. But occasionally they do need stretching. One example is the ligaments in the posterior part of the shoulder, which often *are* tight, but the muscles are long and weak. Here, it is important to stretch the ligaments but not the muscles. An exercise intended to stretch these tight posterior ligaments is where the upper arm is forced across the chest. But more often it actually only stretches the scapular stabilizer muscles, which may already be too long. An athletic trainer or physical therapist will need to ensure that the athlete does stretches very precisely to stretch the right thing without damaging something else.

Flexibility

Flexibility is the ability of a muscle to work over a full ROM—in a short length and a long one. What has been perhaps better appreciated in recent years is that flexibility cannot be created in an isolated muscle. A related property is stiffness, which is the amount of force needed to elongate a muscle. Stiffness is not necessarily bad, but muscle stiffness must be balanced. Often, it is a balance of the flexibility and stiffness of opposing muscles that needs to be corrected, not just a change of one muscle group. We have come to realize that there is such a thing as too much flexibility.

Using the above shoulder example, even if the pectoralis muscle is carefully stretched without damaging the ligaments (i.e., it becomes more flexible), this new elongated status may only last a few minutes. One common reason is that many athletes have a rounded shoulder posture from hours of computer keyboarding, which is what really caused the pectoralis to become short in the first place. Unless the long and weak posterior rotator cuff muscles and scapular stabilizers are corrected, it will be virtually impossible to maintain an elongated pectoralis. The longer-term solution is to stretch the pectoralis by stiffening (strengthening and shortening) the posterior muscles. When your mother told you to sit up straight with your shoulders back, this is what she was intuitively trying to accomplish.

Warm-Up

Studies have clearly shown that warming up muscles before exercise improves performance and prevents injuries. Stretching has been an important part of "warming up" for exercise, but the benefits of warming up have been inappropriately attributed to stretching. Research is showing that traditional stretching is not the best way to warm up. The actual temperature of the muscle is probably the most important factor, and so sitting in a hot tub is almost as effective; warming muscles with moderate dynamic activity is the best. Dynamic movements effectively prepare the muscles for powerful action throughout the needed ROM.

Therefore, we need to reassess how to stretch to get the benefits of a useful increase in balanced ROM, flexibility, and warm-up, without the potential drawbacks or wasted time.

How to Stretch

Stretching can be *static,* where an athlete assumes the stretching position using his or her own opposing muscles. Stretching can also be *passive,* where the force for achieving the stretching position is provided by a partner. In both cases, we seek to stretch to a point of mild discomfort in a muscle for about 30 seconds. While these actions do elongate the muscle, there is increasing evidence that they actually decrease power and speed, at least for several minutes. One study showed that the time for a 600-meter (m) run was improved by 2.4% if athletes had routinely done dynamic exercises, whereas it worsened by 2.5% in the athletes who had done a static stretching routine. Ballistic stretching, which involves swinging a body part to force the joint into an extreme ROM, overactivates some neurological reflexes and may increase the risk of muscle damage.

Dynamic stretching is the currently recommended technique. This involves dynamic movements as opposed to static positions and thus may not appear to be stretching in the former sense. Overload movements such as jumping with weights show even more promise. This activates the nervous system, while static stretching inhibits it. As mentioned above, ballistic stretching also activates the nervous system but probably in a deleterious way. Passive stretching usually stretches more ligaments than muscles and must be used very carefully, if at all.

To show how these various kinds of stretching might be used, let's see how we might approach tight hamstrings. An example of passive stretching would be to have the athlete sit with legs extended and have a partner push on that athlete's back. There is a danger that this will increase ROM, but by stretching back the ligaments, which increases predisposition to back pain, there is little improvement of tight hamstrings. An example of passive stretching would be to have the athlete sit in the same legs-extended position and hold his or her head on the knees. If done correctly, this will result in increased hamstring length but at the cost of short-term decreased strength and power of the hamstrings. Standing on one leg and swinging the other one to the limit of ROM would be ballistic stretching. This may cause tears, again without significantly increasing flexibility of the muscle. Dynamic stretching would involve active movements such as striding, lunging, or whole-body movements similar to the sport itself, all the while maintaining a stable lower back and pelvis. Tai chi, yoga, and pilates often include this type of movement. It is also the essence of "core" training that is critical to all musculoskeletal health.

Dynamic stretching results in a durable rebalancing of muscle strength, flexibility, and stiffness and does not damage the ligaments.

An example of how stretching is related to core strength is what one well-known physical therapist calls the "tail wagging the dog." Athletes with strong legs may produce undesired motions and pain in the back and pelvis, because the back and pelvis (core) are not strong enough to stabilize the leg motion. In this situation, the core muscles are less stiff (more flexible) than the leg muscles. The long-term solution to stretch the "tight" leg muscles is to "stiffen" the core muscles. Doing such rebalancing with isolated stretching of the leg muscles is virtually impossible, while real-world movements of dynamic stretching done with proper form will create a practical balance of flexibility.

Conclusion

In summary, warming up before exercise continues to be very important, but stretching, at least passive or static stretching, has little to no function in a pre-exercise routine. It may have limited benefit after exercise, where at least it has little deleterious effect. Warming up should be done with moderate activity similar to the sport to be undertaken. Muscle flexibility and ROM are best improved with a careful long-term training program. Muscle strength and power, working from a strong core, are developed gradually over the needed ROM. This usually entails sportlike activities done with more attention to form than force.

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See also Preventing Sports Injuries; Static Stretching; Strains, Muscle

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Subarachnoid Hemorrhage

Subarachnoid hemorrhage occurs when there is bleeding into the space between the two innermost protective coverings surrounding the brain, the pia mater and the arachnoid mater. A subarachnoid hemorrhage most often occurs as the result of significant head trauma and is usually seen in the setting of skull fractures or injuries to the brain itself. In this setting, the presence of a subarachnoid hemorrhage has been linked to significantly worse outcomes, although it is unclear whether the presence of the blood in the subarachnoid space is directly responsible or whether it is just a marker for a very serious injury. In either case, a subarachnoid hemorrhage is typically symptomatic, with headache and an alteration of consciousness being common. Once identified, the subarachnoid hemorrhage requires immediate medical attention, and quick intervention is necessary to improve the chance of a positive outcome.

Anatomy

The brain is protected inside the skull by three separate layers of tissue (meninges). The innermost layer, the *pia mater*, is a thin and delicate membrane that lies on the surface of the brain. The second layer, the *arachnoid mater*, covers the brain and pia mater but does not follow the contour of the involutions of the brain. The outermost layer, the *dura mater*, provides a thicker and tougher layer of protection.

These layers define three potential spaces for blood to collect. The *epidural space,* between the skull and the dura; the *subdural space,* between the dura and the arachnoid layer; and the *subarachnoid space,* between the arachnoid and pia layers—each having their own potential sources of hemorrhage. The pia mater is too closely adhered to the brain and too fragile to act as a barrier for blood, and therefore, there is no potential space between the pia and the brain for a hemorrhage to form. A subarachnoid hemorrhage is simply defined as the presence of blood in the subarachnoid space.

Mechanism of Injury

The subarachnoid space is prone to blood collection whenever there is damage to any of the cerebral blood vessels that travel beneath the arachnoid layer, in close proximity to the surface of the brain. Subarachnoid hemorrhage can also occur when there is a substantial injury to the brain tissue itself. In either case, this type of hemorrhage is most often the result of a significant mechanical force applied to the skull. Accompanying skull fractures are common, as are other types of bleeding such as epidural and intracerebral hematomas. This mechanism is relatively rare in sports, especially in those that require the use of a helmet, as long as the helmet is used properly. It is still possible in any sport, however, and more likely when there has been a significant force applied directly to the skull.

Subarachnoid hemorrhages can also occur spontaneously. In these cases, approximately 85% of the hemorrhages are the result of a ruptured cerebral aneurysm. Other causes of spontaneous subarachnoid hemorrhage include arteriovenous malformations, anticoagulation therapy such as coumadin, and the use of certain illicit drugs such as cocaine.

Risk Factors

In the case of the subarachnoid hemorrhage that is caused by an athletic injury, the baseline risk is primarily a function of the type of sport being played, the equipment being used, and the playing technique of the athlete. Additional risk, although hard to quantify, likely exists for athletes who have abnormal vascular anatomy, such as an aneurysm or arteriovenous malformation. Otherwise, the risk of developing a subarachnoid hemorrhage is defined by the nature of the injury and the severity of the impact. Certain sports that involve high velocities and little, if any, protective equipment, such as soccer and field hockey, may also pose additional risk.

In the case of most spontaneous subarachnoid hemorrhages, the risk is determined mainly by the size and location of any vascular abnormality. Although it can be difficult to accurately define the risk of any one aneurysm rupturing, a general rule is to take a conservative approach of repeat neuroimaging for any aneurysm 10 millimeters (mm) in diameter or less. The size and location of aneurysms larger than 10 mm should be carefully considered before undergoing a procedure designed to prevent rupture in the future.

Signs and Symptoms

When a subarachnoid hemorrhage is secondary to head trauma, there is typically a constellation of symptoms similar to that seen in all serious head injuries that includes confusion or loss of consciousness, memory loss, dizziness or unsteadiness, lack of coordination, nausea and/or vomiting, or sleepiness. If the patient is lucid enough to describe symptoms, he or she will typically describe an extremely severe headache. While the subarachnoid hemorrhage may not be directly responsible for neurological deficits such as numbness or weakness on one side of the body, these signs may be present as a result of concurrent injury to the brain.

In the setting of a spontaneous subarachnoid hemorrhage, the hallmark symptom is known as the "thunderclap headache." This headache occurs quite suddenly and is severe. It is often described by patients as feeling like somebody hit them on the head with a blunt object. The sudden nature and severity of this headache are distinct and should always warrant consideration of a subarachnoid hemorrhage as the cause.

Clinical Evaluation

With any athletic head injury, care should be taken on the field to first assess the "ABCs" (airway-breathing-circulation) and evaluate the possibility of cervical spine trauma, instituting cervical immobilization when appropriate. The level of consciousness should then be noted using the Glasgow Coma Scale. Any language, memory, or orientation abnormalities should also be noted. A physical examination should then be performed to evaluate for skull fracture or any focal neurologic abnormality, including pupillary, visual field, and funduscopic examinations, followed by a careful assessment of strength, sensation, reflexes, coordination, and gait. Any evidence of fracture or focal neurologic abnormality warrants activation of emergency medical services.

Following the on-field assessment, appropriate monitoring and serial examinations should be performed to document any changes in signs or symptoms. If the situation gets worse, the patient should be further evaluated in a hospital setting. Care should be taken to establish an accurate timeline of events, and the accurate documentation of findings will help clarify the athlete's postinjury course.

Diagnostic Tests

The presence of a subarachnoid hemorrhage is usually confirmed with a computed tomography (CT) scan of the head. Magnetic resonance imaging (MRI) of the brain can also be used. While MRI may provide more information regarding damage to the brain itself, it is more expensive, requires more time, and is not available at every medical facility. The initial diagnosis, therefore, is typically made with a CT scan. If the clinical suspicion is high enough but the CT of the head is normal, a lumbar puncture can be performed as an alternative method to establish the diagnosis. If a subarachnoid hemorrhage is present, the cerebrospinal fluid that is obtained via the spinal tap will almost always have evidence of blood or blood products. In the case of spontaneous subarachnoid hemorrhages, an intravenous, catheter-based procedure, a cerebral angiogram, is the most useful test for establishing the source of the bleed.

Management

Once the "ABCs" have been addressed, the patient is in the appropriate medical facility, and the patient is medically stable, the next step should be to establish the source of the hemorrhage. Further management depends on the identified cause. In the setting of sports trauma, the cause is likely known (a direct force to the skull). In these cases, there are likely concurrent injuries that need attention, such as a skull fracture. Neurosurgical consultation is required to determine the next steps in management, which could include a catheter-based procedure, surgery, or the placement of a device to monitor the pressure inside the skull. Blood in the subarachnoid space can cause the surrounding arteries to spasm, increasing the chances of further damage to the brain. Medicines can be used to help prevent this phenomenon, and further diagnostic tests can help monitor the cerebral vasculature.

Prevention

As with the prevention of other head injuries in athletics, proper technique, well-fitted and certified equipment, and adherence to the rules of play are paramount. The prevention of spontaneous subarachnoid hemorrhages is applicable only in very specific situations. If an athlete has two or more first-degree relatives (father, mother, siblings), some studies have shown that screening for aneurysms is warranted. If an aneurysm is identified, it may then be evaluated further for the possibility of performing a procedure to reduce the risk of rupture in the future. These decisions are best made carefully and after direct consultation with a vascular neurosurgeon.

Return to Sports

No athlete should return to participation in contact sports as long as he or she is still symptomatic from any head injury. In the case of a subarachnoid hemorrhage, the decision to return to sporting activity should be made very carefully and with the mechanism of the hemorrhage in mind.

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See also Concussion; Epidural Hematoma; Head Injuries; Intracranial Hemorrhage; Neurologic Disorders Affecting Sports Participation; Subdural Hematoma

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Subdural Hematoma

Subdural hematomas are a type of head injury that involves bleeding into the space between the brain and its outermost protective covering, the dura. They typically result when a traumatic force applied to the head creates significant fast-changing velocities of the contents inside the skull. The expanding hemorrhage can increase the pressure inside the skull and compress the underlying brain tissue. While subdural hematomas are relatively uncommon in sports, they are very serious injuries that can lead to significant disability or death. Early recognition of the warning signs and quick medical attention are paramount to a good outcome.

Anatomy

The brain is protected inside the skull by three separate layers of tissue (meninges). The innermost layer, the *pia mater*, is a thin and delicate membrane that lies on the surface of the brain. The second layer, the *arachnoid mater*, covers the brain and pia mater but does not follow the contour of the involutions of the brain. The outermost layer, the *dura mater*, provides a thicker and tougher layer of protection.

These layers define three potential spaces for blood to collect. The *epidural space,* between the skull and the dura; the *subdural space,* between the dura and the arachnoid layer; and the *subarachnoid space,* between the arachnoid and pia layers—each with their own potential sources of hemorrhage. The pia mater is too closely adhered to the brain and too fragile to act as a barrier for blood, and therefore, there is no potential space between the pia and the brain for a hemorrhage to form.

Mechanism of Injury

A network of veins traverses the space between the surface of the brain and the dura. These veins, the *bridging veins*, can tear if the contents of the skull experience sudden changes in velocity. Blood leaking from the bridging veins then collects in the subdural space, creating a hematoma. The size of the hematoma and the speed with which it expands depend primarily on the number and size of the tears in the bridging veins. Given that the blood in the bridging veins is coming from the venous side of the circulatory system and is therefore under less pressure, subdural hematomas typically expand at a much lower rate than hematomas that are formed from arterial blood, such as epidural hematomas. The expanding subdural hematoma increases the intracranial pressure and can lead to damage of the underlying brain.

Subtypes

Subdural hematomas are often classified based on their acuity into *acute, subacute,* and *chronic* subtypes. Acute subdural hematomas are extremely dangerous and frequently lethal without quick surgical intervention. Symptoms develop quickly, and mortality rates are estimated between 60% and 80%. Subacute subdural hematomas become symptomatic over several hours to days and carry a better prognosis. Chronic subdural hematomas develop over days to several weeks and are common in elderly individuals. Frequently, they are only mildly symptomatic or without symptoms completely. In these cases, the bleeding is self-limited, and no surgery or acute intervention is required. In the athletic population, a subdural hematoma caused by a physical impact is more likely to present as an acute or subacute subtype.

Risk Factors

Any process that increases the distance that the bridging veins must travel to cross the subdural space increases the risk of tearing and, therefore, of hematoma formation. Brain atrophy is probably the biggest contributor of increased risk. Subdural hematomas, therefore, become more common as people age and the brain undergoes the natural process of age-related atrophy. Processes that increase brain atrophy, such as Alzheimer disease or chronic alcohol exposure, can increase the risk even further.

While brain atrophy increases the risk of developing a subdural hematoma, it also decreases the speed and severity of the related symptoms. This is due to the fact that brain atrophy provides more space for the hematoma to expand before it begins to increase intracranial pressure and interfere with brain function. Conversely, younger patients, without atrophy, will typically develop symptoms over a shorter period of time.

Signs and Symptoms

As mentioned above, the signs and symptoms of subdural hematoma typically have a slower onset than those seen in epidural hematomas. Depending on the particular subtype, symptoms can develop within the first 24 hours or may be delayed in onset by several days or weeks. The speed with which the majority of symptoms develop depends mainly on the degree of tearing of the bridging veins and the amount of space available for the hematoma to occupy before intracranial pressures begin to increase. Headache, either constant or fluctuating, can certainly occur during any stage of the process. Other common signs or symptoms that may occur as the result of a subdural hematoma include, but are not limited to, the following:

- Loss of consciousness
- Numbness
- Decrease in consciousness
- Seizure
- Amnesia
- Lethargy
- Disorientation
- Slurred speech
- Blurry vision
- Dizziness
- Nausea or vomiting
- Weakness
- Balance difficulty
- Personality changes

It should be noted that the presenting signs and symptoms of subdural hematoma are similar to those of other head injuries, including concussion. Oftentimes, the main difference is in the time course of symptoms. If any athlete develops new symptoms several minutes after a witnessed impact or if there is any perceived clinical worsening, emergency medical services should be notified.

Clinical Evaluation

As with any athletic head injury, care should be taken on the field to first assess the "ABCs" (airway-breathing-circulation) and evaluate the possibility of cervical spine trauma, instituting cervical immobilization when appropriate. The level of consciousness should then be noted using the Glasgow Coma Scale. Any language, memory, or orientation abnormalities should also be noted. A physical examination should then be performed to evaluate for any focal neurologic abnormality, including pupillary, visual field, and funduscopic examinations, followed by a careful assessment of strength, sensation, reflexes, coordination, and gait. Any focal neurologic abnormality warrants activation of emergency medical services.

Following the on-field assessment, appropriate monitoring and serial examinations should be established to document any changes in signs or symptoms. If the situation gets worse, the patient should be further evaluated in a hospital setting. Care should be taken to establish an accurate timeline of events, and accurate documentation of findings will help clarify the athlete's postinjury course.

Diagnostic Tests

The presence of a subdural hematoma is usually confirmed with a computed tomography (CT) scan of the head. Magnetic resonance imaging (MRI) of the brain can also be used. While the MRI scan may provide more information regarding damage to the brain itself, it requires more time for image acquisition and is not available at every medical facility. The initial diagnosis, therefore, is typically made with a CT scan.

Management

The management of a patient with a subdural hematoma will depend greatly on the extent of the bleed, its location, and the overall clinical status. Small, asymptomatic subdural hematomas can be managed conservatively with serial CT scans of the head to assess for any interval change in hemorrhage size. Larger hemorrhages, or those that are producing a more significant clinical compromise, should be emergently evaluated for surgical decompression.

Prevention

As with other head injuries in athletics, proper technique, well-fitted and certified equipment, and adherence to the rules of play are paramount in preventing a subdural hematoma.

Return to Sports

No athlete should return to participation in contact sports as long as he or she is still symptomatic from any head injury. In the case of a subdural hematoma, if surgical intervention was required, contact sports should be avoided indefinitely. For smaller, less complicated hemorrhages, there are no clear return-to-play guidelines, but a conservative approach is encouraged.

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See also Concussion; Epidural Hematoma; Head Injuries; Intracranial Hemorrhage; Neurologic Disorders Affecting Sports Participation; Subarachnoid Hemorrhage

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Sudden Cardiac Death

Sudden cardiac death (SCD) in athletes has recently generated much discussion as well as some controversy in the field of sport and exercise medicine. The possibility that an athlete who epitomizes health and longevity could suddenly die in the midst of athletic competition or practice is highly unnerving and unsettling. It is difficult for all of us, health professionals and the lay public alike, to fathom this apparent paradox, often leading to increased scrutiny and attention when a tragic death does occur within a community and to question whether something more can or should be done to prevent this from occurring in the first place.

It is important to remember that sports activity itself is not lethal, but rather it may be the trigger for sudden cardiac arrest (SCA) in an athlete whose susceptibility is increased due to an underlying, silent cardiac condition. It is not unusual for the athlete to not have any symptoms, or perhaps not have recognized them, before the actual episode leading to SCA and death.

Causes

Fundamentally, the heart is a muscle, and its function is to contract and pump blood, carrying oxygen to the body. Unlike other muscles, the heart has an elaborate electrical conduction system that regulates or signals its own activity.

The most common cause of sudden cardiac death in the United States in those above 35 years of age is hypertrophic cardiomyopathy (HCM). In adults above 35 years of age, the number one cause of SCD is atherosclerotic coronary artery disease.

Hypertrophic Cardiomyopathy

In HCM, the heart is thickened abnormally, and usually asymmetrically, and is at risk for abnormal function. There is a genetic basis for this condition; however, the physical expression of the condition is variable. There are much fewer cases of diagnosed HCM than people with the genetic defect, which is believed to be about 1 in 500 people. It is not clear what other factors contribute to an athlete actually being diagnosed with HCM.

Diagnosing HCM, as with other cardiac conditions that cause SCD, starts with having a low threshold of suspicion for findings in the athlete's history, physical exam, and electrocardiogram (EKG; a tracing of the electrical activity of the heart). Listening to the heart with a stethoscope (cardiac auscultation), a certain type of heart murmur consistent with turbulent blood flow within the heart may be detected in an athlete with HCM. There are, however, a number of types of heart murmurs, and the presence of a murmur can be normal or benign. An echocardiogram may be obtained to help confirm the presence of HCM.

It is worth noting that there are normal physiologic adaptations of the heart in response to exercise. The condition of "athlete's heart" encompasses normal cardiac responses to exercise, including heart muscle hypertrophy and electrical changes as evidenced on an EKG. Because of the clinical overlap in findings between an athletic heart and one with HCM, the diagnosis of one versus the other can sometimes be challenging.

Coronary Atherosclerotic Disease

In adults above 35 years of age, coronary atherosclerotic disease (CAD) can lead to sudden death in exercising individuals. Over time, susceptible individuals will build up fatty plaque within the arteries, which causes significant narrowing. As exertion increases, as during exercise, the heart requires more oxygen; the narrowed artery can limit the amount of blood flow that can get to the heart. The oxygen demand can outpace the supply, causing heart muscle ischemia; this in turn can disrupt the electrical signal, throwing the heart into a lethal rhythm, as in ventricular fibrillation. The atherosclerotic plaques may also break off, especially during times of high demand or stress on the heart; the plaque can then limit or cut off blood flow distal to the blockage, causing heart muscle ischemia and tissue death. Diagnosis of CAD can be supported indirectly with a variety of cardiac stress tests and directly with invasive cardiac catheterization. Of note, changes of CAD have been found in people in their 20s and younger and so may contribute to some cases of SCD in this age-group as well.

Other Causes

Other, less common causes of SCD in young people include structural and electrical abnormalities such as, but not limited to, congenital anomalies of the coronary arteries, arrhythmogenic right ventricular dysplasia (ARVD), myocarditis, and conduction abnormalities such as long QT syndrome.

Congenital coronary artery anomalies are normal anatomic variants. In certain alternate locations, the coronary artery can pass between structures such as the back of the heart and aorta, which can in turn cause the compression of the artery and thereby limit flow, especially during exercise. The consequence is similar to what occurs in coronary artery disease in that the decreased flow leads to myocardial ischemia, heart muscle death, and fatal arrhythmia. Diagnosis is difficult, and this condition is typically diagnosed at the autopsy after an SCD event; a cardiac CT (computed tomography) angiogram or cardiac catheterization may be helpful if clinically suspected.

In ARVD, the heart muscle is affected, undergoing changes that replace the normal healthy cardiac muscle tissue in the right ventricle with abnormal, irregular, disorganized, nonfunctioning fibrofatty connective tissue. Fibrofatty tissue can be thought of as scar tissue except that unlike with typical scar tissue formation, there is no precipitating injury or damage to the muscle in patients with ARVD. Family history, and thus a genetic component, may be contributing factors. The mechanism that leads to SCD is likely the result of arrhythmia that occurs as the conduction system tries and fails to work properly in tissue that is abnormal and in disarray. An EKG may raise clinical suspicion, and further imaging with echocardiogram or possibly cardiac MRI may be indicated for confirmation.

Myocarditis is an acute illness that causes inflammation of the heart muscle as a result of infection with a virus or bacteria. The athlete may experience chest pain, palpitations, and shortness of breath, along with associated systemic signs of fever, myalgia, and fatigue. While there is considerable overlap in the symptoms of myocarditis with severe viral illness such as the "flu," a rapid pulse out of proportion to other features should alert the physician to this possibility. Consider holding the athlete from return to play for several months after the acute illness resolves as the heart muscle may continue to be at risk for a period of time during recovery.

Prolonged QT syndrome describes a certain electrical conduction abnormality within the heart that predisposes the athlete to SCD. There may be a family history of SCA or SCD, and there are at least six genetic variants that have been identified thus far. Diagnosis is confirmed by EKG. There is no cure per se for this, though the risk for SCD may be reduced with appropriate risk stratification and medical management.

Management

Acute

The mechanism by which most cardiac conditions are thought to cause sudden death during exercise pertains to structural changes in the heart that disrupt normal electrical conduction or rhythm. Typically, in SCD, the final lethal heart rhythm resulting in an irregular, chaotic rhythm is due to *ventricular fibrillation.*

Once ventricular fibrillation occurs, an electrical shock delivered by a defibrillator (e.g., an automated electronic defibrillator, or AED, which can be used by a lay person with little to no prior training) must be provided quickly; otherwise, this rhythm is usually fatal. The success of defibrillation declines rapidly by the minute once the heart is in ventricular fibrillation. If successful, the defibrillator shock will restore a normal electrical rhythm to the heart and restore normal blood flow through the body. At the very least, basic resuscitation efforts including calling for help and beginning CPR (cardiopulmonary resuscitation) with regular breaths and chest compressions should be initiated immediately for the fallen athlete with no detectable pulse.

Follow-Up

If an athlete is found to have any of these conditions, he or she may be disqualified from competing in most, but not necessarily all, sports for some period of time. Some conditions are amenable to medical management, including medications, activity modification, and possibly an implanted defibrillator. Treatment may depend on whether the athletes have previously had an event of SCA and survived, whether they have any symptoms related to their cardiac condition, or whether they have any close family members with the same condition who have had an SCA event. None of the medical interventions, however, guarantees the athlete a return to the same low level of risk for SCD that an athlete without any of these conditions has. All these heart conditions place the athlete at increased risk for SCD, and all these athletes need close medical follow-up and monitoring.

Regardless of management, careful consideration should still be given to the athlete's diagnosis, condition, and expected level of function and sports, and the risks and benefits of sports participation should be carefully weighed on an individual or a case-by-case basis.

Prevention

Though SCD is fortunately rare (annual incidence is 1 in 200,000), prevention of SCA and SCD events is the best and optimal approach. Many physicians currently rely on the sports preparticipation screening history and examination to help identify at-risk athletes. (For all 12 elements of the American Heart Association–recommended preparticipation cardiovascular screening steps in athletes, refer to the 2007 article by B. J. Maron et al., published in *Circulation*.) Some of the essential questions that should be asked at all preparticipation physicals include the following:

1. Have you ever passed out while exercising?
2. Have you ever had chest pain, palpitations (rapid or irregular heartbeats), or shortness of breath while exercising?
3. Has there been a sudden, possibly unexplained, death in an apparently healthy, otherwise young relative?

Utilization of the screening EKG in preventing SCA and SCD is currently controversial. The discussion on whether to perform screening EKGs for all athletes is complicated to say the least, and it is beyond the scope of this entry. Factors to consider in the controversy involving EKG screening are the accuracy of the EKGs, the potentially significant number of false-positives (i.e., normal hearts that would look abnormal on EKG), and the effectiveness and financial impact of large-scale mandatory EKG screening (as well as the impact of further testing and subspecialty consultations that the EKG screening would necessitate). This could be very burdensome to an already strained health care system, not to mention the individual athlete and his or her family having to undergo further mandated evaluation prior to participating in sports.

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See also Athlete's Heart Syndrome; Cardiac Injuries (Commotio Cordis, Myocardial Contusion); Preparticipation Cardiovascular Screening; Pulmonary and Cardiac Infections in Athletes

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Sunburn

Sunburn is characterized by skin redness, swelling, tenderness, and blistering in response to sunlight exposure. Given the number of athletes who play outdoor sports, prevention of the negative short- and long-term health effects of sunburn is important.

Sunlight

Sunlight is divided into visible light, infrared radiation, and ultraviolet radiation (UVR). UVR is categorized further into UVA (320- to 400-nanometer [nm] wavelength), UVB (290–320 nm), and UVC (<290 nm) radiation. UVB radiation can lead to the acute skin changes seen in sunburn. It has the ability to directly damage DNA, causing genetic mutations and cancer. UVA radiation is associated with skin wrinkling and may also contribute to some skin cancers. UVC does not contribute to sunburns.

Environmental factors play a role in determining UVR exposure. The stratosphere contains ozone, which absorbs all UVC, high amounts of UVB, and a small amount of UVA radiation. Ozone concentrations vary with temperature, weather, altitude, and latitude. UVB radiation increases by 3% per degree of latitude, and UVR intensity has been found to increase by 4% for every 300 meters (m) of elevation. Midday sunlight passes through less of the atmosphere than at any other point in the day, leading to more UVR exposure during midday hours. Clouds, fog, and haze can decrease UVR by 10% to 90% but never fully block it out. Snow and sand can reflect up to 90% of UVR. Even under water, UVR can penetrate to a depth of 1 m.

Skin Changes

The *epidermis* forms the protective, outermost layer of the skin. The deepest layer of the epidermis is constantly repopulated by new keratinocytes (cells composed of keratin), which migrate superficially, replacing the older keratinocytes and turning over the entire epidermal layer in approximately 28 days. *Melanocytes* (cells that produce melanin) are located in the deepest layer of the epidermis. The melanin is stored in melanosomes, which can be transferred to the keratinocytes. Skin color is influenced by the number and size of melanosomes, the type of melanin they contain, and the rate at which melanin is broken down.

Sunburn occurs as the skin tries to protect itself by absorbing UVR. UVA radiation is partially absorbed by melanin, which produces a darkening of the skin as the melanin is transferred to the keratinocytes. The resulting tan appears immediately after exposure and lasts for a few hours but does not protect the skin against future damage from sun exposure. UVB radiation is responsible for the redness, swelling, tenderness, and blistering that appears 6 to 12 hours after exposure and peaks in effect around 24 hours. These changes are caused by the release of inflammatory mediators, leading to dilation of the blood vessels and increased vascular permeability. In response to the damage, melanocytes accelerate the production of melanin and its transfer to keratinocytes. This results in a darkening of the skin that appears 2 to 3 days after sunlight exposure, persists for days to weeks, and reduces the skin's sensitivity to UVR by two- to threefold.

Risk Factors

Athletes with more melanin, and darker skin, are at lower risk for sunburn, while fair-skinned athletes are more likely to sunburn. But UVR still penetrates the skin and causes damage in people with dark skin. People living at higher altitudes or locations with predominantly sunny climates have an increased risk due to more exposure to sunlight. Sweating has also been found to increase the photosensitivity of the skin and to increase the risk of sunburn.

Signs and Symptoms of Sunburn

Sunburn is characterized by skin that feels hot or warm to the touch along with the development of red or pink skin after exposure to even a brief period of sunlight or other source of UVR. There will likely be discomfort in the affected area and possibly swelling. Fluid-filled blisters may develop on the skin. Headache, fever, and fatigue may also go along with sunburn. Sunburned eyes have a gritty, painful feeling. A few days after sunburn appears, the skin will begin to become flaky and peel.

Most sunburns do not require assessment by a medical provider. However, the following findings with sunburn require evaluation:

- High fever, intense pain, vomiting, diarrhea, or confusion
- Blistering that covers a large part of the body
- Signs of a skin infection (drainage of yellow pus from the area or increased pain or swelling in an affected area)
- Pain that is not adequately controlled with home treatments

Long-Term Complications

Skin photoaging, actinic keratoses (rough, scaly patches of skin), and skin cancer are some of the long-term effects of sun exposure. Over time, sun exposure causes the connective tissues of the skin to weaken, leading to dryer, rougher skin with deep wrinkling. Large brown macules, called solar lentigines (liver spots), can appear on sun-exposed areas. Actinic keratoses are usually white, pink, flesh-colored, or brown patches that commonly develop on the face, ears, lower arms, and backs of the hands. Actinic keratoses occur mainly in fair-skinned individuals who have had a large amount of sun exposure. They are considered precancerous, and they can develop into squamous cell skin cancer. Exposure to UVR, especially UVB radiation, is thought to be the main determinant in the development of basal and squamous cell skin cancers and is also thought to play a role in the development of cutaneous malignant melanoma. An increased prevalence of either precancerous or cancerous skin lesions has been found in professional mountaineers, surfers, marathon runners, and other athletes who practice outdoors.

Prevention

Avoidance of the sun's rays when they are the strongest, generally between 10 a.m. and 4 p.m., is the best recommendation to avoid sunburn. As this is not always possible, protection in the form of clothing, sunglasses, hats, and sunscreen should be used. The sun protection factor (SPF) is a ratio used to indicate the amount of protection against UVB radiation afforded by a given skin protectant compared with unprotected, sun-exposed skin. An SPF of 15 indicates that a person who normally has skin redness after 10 minutes of sun exposure could go in the sun with sunscreen for up to 150 minutes without experiencing the same skin effect.

There are many different agents used in sunscreens. These chemicals protect the skin by both reflecting and dispersing UVR (zinc oxide, titanium dioxide) or absorbing UVR (benzophenones, cinnamates, salicylates, and numerous other compounds). All types of sunscreen should be applied 30 minutes prior to sun exposure and reapplied at least every 2 hours for best protection. Clothing is also an important part of skin protection. Clothes that are tightly woven, loose fitting, dry, unbleached, and made of thicker fabrics increase the UVR protection. Light-colored, cotton, wet, or loosely woven fabrics all offer lower levels of protection. It is also important to wear a broad-brimmed hat and sunglasses that fit close to the face and block out UVR.

Treatment

Once sunburn occurs, skin damage is already present. Treatments are targeted toward symptom relief but do not decrease any of the long-term risks associated with sunlight exposure. It is very important to rule out heat illness in an athlete with acute sunburn. Cool compresses or baths can provide immediate relief. Skin-moisturizing creams, aloe vera lotion, and other over-the-counter emollients containing combinations of menthol, camphor, pramoxine, calamine, or lidocaine can be used to keep the sunburned skin moist and ease some of the tenderness. Oral pain medication such as ibuprofen or other nonsteroidal anti-inflammatory drugs (NSAIDs) have been found to be most beneficial if taken immediately after the signs of sunburn begin to appear. Oral and topical corticosteroids have been found to have minimal impact on sunburn. If blistering appears, it is best to leave the blisters intact to decrease the risk of skin infection. Eventually, the skin will begin to peel as the body removes the damaged cells from its top layers. Moisturizing creams are recommended during this process.

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See also Cholinergic Urticaria; Dermatology in Sports; Head Injuries; Heat Illness; Skin Disorders Affecting Sports Participation; Sunburn and Skin Cancers

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Sunburn and Skin Cancers

The incidence of skin cancer has been increasing in the general population for the past several years, and the amount of sun exposure remains the most important risk factor. Athletes should be taught basic prevention measures, such as avoiding sunburn by using sunscreen and protective clothing as well as avoiding sun exposure during peak ultraviolet B (UVB) hours. Sunburn is the painful, erythematous reaction of the skin in response to excessive sun exposure that often afflicts athletes who spend many hours training outdoors. In the United States, 30% to 40% of adults and 70% to 85% of children and adolescents have reported at least one occurrence of sunburn in the previous year. Sunburns not only cause acute discomfort after sun exposure but may ultimately lead to skin cancer.

Anatomy

The skin is the body's largest organ, covering the entire outside of the body and weighing about 6 pounds (lb; 1 lb = 0.45 kilogram). In addition to serving as a protective shield against infection, the skin also regulates body temperature and stores water, fat, and vitamin D. The skin is made up of three layers, each of which has a specific function: (1) the *epidermis*, which provides a barrier to infection; (2) the *dermis*, which is made of connective tissue that cushions the body from stress and strain; and (3) the *hypodermis* layer, which is mainly for fat storage.

Causes

Sunburn is a burn on the skin caused by UV radiation. The damaging effects of UV radiation can occur after as few as 15 minutes of sun exposure for light-skinned persons. The symptoms of sunburn do not begin until 2 to 4 hours after the damage has occurred. Minor sunburn is a first-degree burn that turns the skin pink or red. Prolonged sun exposure can cause blistering and is described as a second-degree burn. Sunburn never causes a third-degree burn or scarring.

Frequent sun exposure and suntans can also cause premature aging of the skin (wrinkling, sagging, and brown sunspots). Also, repeated sunburns increase the risk of skin cancer in the damaged areas. Each episode of blistering sunburn doubles the risk of developing *malignant melanoma,* which is the most serious type of skin cancer.

Symptoms

Mild and uncomplicated cases of sunburn usually result in minor skin redness and irritation. Initially, the skin turns red between 2 to 4 hours after exposure and feels irritated. The peak effects are noted at 12 to 24 hours. Other common symptoms of sunburn involve flulike symptoms, including fever, chills, nausea, and vomiting. More severe cases have complications such as severe skin burning and blistering, massive fluid loss, electrolyte imbalance, and infection.

Symptoms of skin cancer may vary from a melanocytic lesion that is completely asymptomatic to a painful bleeding erosion characteristic of squamous cell carcinoma. Routine skin evaluation by a medical provider has been recommended, because most skin cancers are asymptomatic and are found on routine screening examinations.

Diagnosis

Diagnosis of sunburn is usually not difficult and could be made based on symptomatology and a recent history of sun exposure. The appearance of a characteristic reaction on sun-exposed skin with sparing of skin that was covered or shaded is usually sufficient to diagnose sunburn.

The first step in detecting skin cancer begins with each individual. It is recommended that each person examine his or her skin once a month for any suspicious changes, such as moles that have changed in color, size, and/or surface texture. Also, sores that do not heal may also indicate cancerous or precancerous conditions of the skin that need attention.

Actinic keratoses are precancerous conditions that typically occur in individuals with a long history of sun-damaged skin. Lesions appear as rough, crusty bumps on the back of the hands, lips, face, scalp, or neck that may itch or feel tender. If untreated, these bumps may develop into skin cancer.

Basal cell carcinomas show up as flat, firm, pale areas or as small raised pink or red pearly bumps that may appear anywhere on the body that is regularly exposed to the sun, such as the head and neck. They grow slowly and rarely spread to other parts of the body.

Squamous cell carcinomas appear as nodules or as red, scaly patches, typically on the ear, face, lips, and mouth. These patches eventually develop into large masses. This type of skin cancer is more likely to spread to other parts of the body than basal cell carcinoma. Squamous cell carcinomas are highly treatable, with a 95% cure rate.

Melanoma can develop from a preexisting mole or on clear, smooth skin. Unlike a noncancerous mole, melanoma is irregularly shaped or has irregular borders and is black, brown, or tan. The leg is the most common site where melanoma is found in women, and the trunk is the most common site in men. Early diagnosis is the most important factor to improve the prognosis in this potentially fatal disease.

Treatment

A number of treatments aimed at altering the course of sunburn have been prescribed, but none will immediately reverse the damage from sunburn. These treatments include nonsteroidal anti-inflammatory drugs (both topical and oral), cold compresses, aloe vera gel, and topical anesthetics such as benzocaine. Currently, treatment of sunburn is only symptomatic, and athletes should avoid further sun exposure until the symptoms resolve.

There are many treatments for skin cancer, which vary depending on the type of skin lesion. Cryotherapy is commonly used on actinic keratosis. This treatment includes applying liquid nitrogen to the lesion for 3 to 5 seconds, which causes the lesion to slough off within a few days. Another common method for treating all other skin cancers is surgical excision of the affected area of skin. The physician cuts out or excises the cancerous tissue and a surrounding margin of healthy skin. A wide excision of skin is often used to ensure that no malignant cells remain.

Laser therapy may be used to produce a precise, intense beam of light to vaporize growths. Generally, this will cause little damage to the surrounding tissue and minimal bleeding, swelling, and scarring. Mohs surgery is a procedure for large, recurring, or difficult-to-treat skin cancers, which may include both basal and squamous cell carcinomas. The surgeon removes the skin growth layer by layer, examining each layer under the microscope until no abnormal cells remain. This procedure allows cancerous cells to be removed while leaving as much surrounding healthy skin as possible.

Curettage and electrodesiccation are a procedure in which, after removing most of the growth, the doctor scrapes away layers of cancer cells using a circular blade called a *curet*. An electric needle destroys any remaining cancer cells. This procedure is common in treating small or thin basal cell cancers and leaves only a small, flat, white scar.

Radiation therapy may be used to destroy basal and squamous cell carcinomas if surgery is not an option. Systemic chemotherapy can be used to treat skin cancers that have spread to other parts of the body. Photodynamic therapy (PDT) is a treatment that destroys skin cancer cells with a combination of laser light and drugs that makes cancer cells sensitive to light. Photodynamic therapy for precancerous skin lesions is currently available by prescription.

Prevention

Limiting sun exposure is the most important part of preventing sunburn; when avoiding exposure is not possible, proper use of sunscreen and protective clothing is vital. Routine self-examination followed by regular skin checks by your health care provider is the best way to detect any skin abnormalities that could be diagnosed as skin cancer. The American Academy of Dermatology has developed an easy-to-use method to evaluate your skin for melanoma, titled the "ABCDs of melanoma." Look for the following:

*A*symmetry: One half of the spot is not shaped like the other half.

*B*order irregularity: The border is poorly defined, ragged, blurred, notched, or "scalloped."

*C*olor: Across the mole, there are various shades of tan, brown, black, and sometimes red, white, and blue.

*D*iameter: The mole is greater than 6 millimeters.

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Superficial Heat

Application of superficial heat is an adjunct to a therapeutic treatment program in the rehabilitation of an injury. Superficial heat is a modality that provides pain control, promotes muscle relaxation, and increases blood flow to the area. Types of superficial heat include fluidotherapy, hot packs, and paraffin. Indications for use are joint stiffness, muscle spasm, pain, and weakness. The normal responses to application of superficial heat are decreased pain, swelling, and muscle spasm; an increase in circulation; and mild redness of the skin. The abnormal responses to superficial heat are increased pain, fainting, bleeding, and prolonged skin redness and/or blistering.

Fluidotherapy

Fluidotherapy is a modality that uses air-fluidized solids called Cellex (particles made from corn cobs), which are placed into a container. Heated air is then blown into the enclosure, causing the Cellex to circulate. An arm or leg can be inserted into the container, and the warmed, moving Cellex flows around the injured arm or leg. Fluidotherapy provides localized heat while the patient completes active or passive range-of-motion exercises.

Contraindications include respiratory distress, skin disorder, corn allergy, circulatory obstruction, arterial occlusion, blood clots, lymph occlusion, acquired immune deficiency syndrome (AIDS), poor sensation, hepatitis, chicken pox, typhoid, paratyphoid, sepsis, and/or other infectious diseases.

Precautions should be taken in the case of an open wound or poor mental status.

Hot Packs

Hot packs provide superficial moist heat via conduction. They are applied to the injured area for 15 to 20 minutes. Hot packs are usually made of canvas covers filled with bentonite, hydrophilic silicate, and other heat-retaining substances. Some hot packs are stored in water with a controlled temperature of approximately 160 °F (71.1 °C). Contraindications include fever, acute inflammatory conditions, active bleeding, long-term steroid therapy, blood clots, and malignancy. Precautions are necessary in case of pregnancy, sensory or circulatory impairments, older age, and the inability to stay still for 15 to 20 minutes. A thick protective barrier must be placed between the hot pack and the skin to avoid burning.

Paraffin

Paraffin application is a method of applying superficial heat that uses conduction through a mixture of paraffin wax and mineral oil in a 6:1 or 7:1 ratio. The heating container should maintain the temperature of the paraffin at 118 to 130 °F (47–54.4 °C).

Contraindications include open wounds, skin lesions, fever, acute inflammatory conditions, active bleeding, long-term steroid therapy, and blood clots. Precautions should be taken in case of poor mental status, age, sensory loss, and newly healed skin.

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See also Cryotherapy; Electrotherapy; Hydrotherapy and Aquatic Therapy; Principles of Rehabilitation/Physical Therapy

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Superior Labrum From Anterior to Posterior (SLAP) Lesions

A *SLAP* (superior labrum from anterior to posterior) *lesion* is a tear in the superior part of the shoulder joint lining (glenoid labrum) in an anterior-posterior direction. Typical causes of this tear include, but are not limited to, the following:

1. Sports: particularly activities that induce compressive forces on the shoulder, such as baseball, volleyball, and tennis
2. Overuse: doing too much at one time (e.g., overhead activity) coupled with severe tension on the biceps muscle tendon
3. A sudden increase in activity, such as lifting a very heavy barbell
4. A fall onto an outstretched arm.
5. An imbalance between the muscles and ligaments that provide stability to the shoulder joint

To understand the mechanism of the injury, a basic understanding of the anatomy of the involved structures is necessary.

Basic Anatomy

The shoulder is a ball-and-socket joint; the glenoid fossa (cavity) of the scapula (shoulder blade) is the socket and is composed of bone at the base and lined with cartilage. It is surrounded with additional lining at the circular rim by the *glenoid labrum* (from the Latin meaning "upper lip"), which is composed of cartilage, providing a cushion. It also makes the socket deeper and provides more stability to the joint, permitting easier movement with minimal friction. The ball of the joint is the proximal part of the humerus (upper arm bone) that is embedded in the glenoid fossa and surrounded by the glenoid labrum.

Several muscles and ligaments help with movement by initiating, maintaining, and balancing the forces that enable the ball to remain in the joint. The major muscles involved include the deltoid, biceps, and supraspinatus. The glenohumeral ligaments attach to the lesser tubercle of the humerus and the lateral part of the scapula. The semicircular ligament runs side to side, which is very important for stability. Synchronous motion of the ligaments and muscles provides stability and strength to the shoulder. Major motions include abduction (motion away from the body), adduction (motion toward the body), and internal and external rotation.

The main muscles are as follows:

- The *deltoid muscle* covers the shoulder joint and provides a smooth contour of the shoulder. It acts as abductor of the arm and is innervated by the axillary nerve. Any injury to this nerve will affect this function of the deltoid muscle. It originates from the humerus and inserts into the shoulder joint, covering the joint from three surfaces.
- The *biceps muscle* acts to flex and supinate (turn up) the arm. It originates at the elbow and inserts into the glenoid labrum superiorly by its tendon (a band of dense fibrous tissue that unites muscle to bone). The muscle is innervated by musculocutaneous nerve.

The word *tendon* comes from the Latin word meaning "to stretch." The tendon transmits force when the muscles contract. Ligaments are similar, but they originate in bone and insert to bone.

Injuries can occur in a variety of ways—if a patient tries to lift a heavy weight, a lot of force will be exerted on the tendon and its area of insertion (in this case, the glenoid labrum). Two possible injuries could occur. The tendon could get inflamed and begin to tear from the area of insertion or, in the worst case, avulse (snap off), possibly taking a part of the glenoid labrum (cartilage) as well, causing a SLAP tear.

The supraspinatus is part of the rotator cuff muscles, which also include the infraspinatus, teres minor, and subscapularis. The supraspinatus originates at the scapula, or wing bone, passing under the acromion and inserting into the ball of the humerus, and is innervated by the suprascapular nerve. It causes abduction of the arms and is the most commonly injured among the rotator cuff muscles, especially with eccentric repetitive load applied to the muscle.

The infraspinatus originates at the shoulder blade and inserts at the humeral head, which is encapsulated under the coracoacromial arch. It laterally rotates the arm and is innervated by the suprascapular nerve.

Because the muscle tendons pass through a very narrow area, they are very susceptible to injuries. In addition, any buildup of calcification (bone spurs) may also cause problems.

The shoulder has two sets of muscles and ligaments, both with differing functions. Some hold the joint in place, whereas the others permit free motion of the shoulder and upper arm in all directions with ease and without any limitation.

Many factors come into play to ensure good shoulder movement.

The mechanism of injury is not fully understood; however, one scenario is that a sudden contraction of the biceps muscle causes stress on the tendon that is attached to the labrum, and to prevent dislocation of the shoulder, the labrum will tear.

As an example, throwing a ball in a sport such as baseball can cause shoulder injury. The technique of throwing has six phases, each of which can induce certain stresses on the shoulder. In the SLAP tear injury, the late cocking and deceleration phases are the primary contributors of injury in baseball players.

Phase 1: Wind-up is the phase during which there is minimal stress to the shoulder.

Phase 2: Early cocking is a slight-load phase, where the shoulder moves into abduction (away from the center of the body).

Phase 3: Late cocking begins with the stride leg being planted and ends with the shoulder in maximum external rotation, up to 180°. Muscle activity reaches its maximal stress in this phase.

Phase 4: Acceleration rotates the shoulder to the ball release point of 90° rotation, maintaining shoulder abduction.

Phase 5: Deceleration is the most harmful phase of the throwing cycle, where maximal eccentric contractions occur in several muscles to prevent rotation of the arm.

Phase 6: The follow-through is the phase where the body is rebalancing, and the body moves forward until the motion stops and returns to resting levels.

The entire throwing motion, through all six phases, will take less than 2 seconds.

Diagnosis

The patient's history is the key to the diagnosis, and a typical patient may present with complaints that include the following:

- General weakness
- Anterior-lateral sharp pain that gets worse with lifting items
- A perception of the shoulder being unstable
- Diminished arm range of motion
- Feeling as if the joint needs lubrication, due to the consciousness of internal friction
- An increase in pain when trying to do activities that require the arm to be up and behind
- A history of overuse and repetitive activities
- Trauma such as falling on an outstretched arm, which may force the biceps and other shoulder muscles to contract or stretch in unsynchronized actions that may cause a tear

The patient may often be an athlete, especially one involved in sports that require contraction of the biceps, such as swimming, racquetball, football, and so on.

Diagnosis of a SLAP Lesion

Physical Exam

The patient's history is the primary key to the diagnosis, along with the physical exam. The physical exam should include the following:

- Observe the patient for any swelling, deformity, or color changes.

- Evaluate active range of motion: The patient moves his or her shoulder and arms in all directions without assistance from the examiner.
- Evaluate passive range of motion: The examiner moves the shoulder and arms in all directions without the patient's help.
- Evaluate for isometric resistance and muscle strength of the shoulder joint: The patient moves the shoulder or the arm while the examiner tries to prevent the movement by applying force.
- Palpate the joint of the patient for tenderness.
- Evaluate the shoulder and upper arm for sensory deficit.
- Evaluate the blood flow by palpating the pulse at the biceps area.
- Evaluate for osteopathic somatic dysfunction, incorporating manual medicine to evaluate the joint for any restrictions of movement.
- Incorporate special tests that primarily stress the shoulder joint, muscles, and tendons:
  - *Speed test:* The patient flexes the forearm against resistance from the examiner. Pain will increase at the area where the biceps tendon passes to the joint.
  - *Yergason test:* The patient flexes the forearm toward the body while the examiner resists, leading to an increase in pain.

Radiologic studies are not always helpful as an X-ray will not help establish a diagnosis.

For a clinically suspected tear, the orthopedic surgeon can obtain an arthrogram by injecting dye into the joint and obtaining an X-ray to make the lesion more visible. Arthroscopy may also be done, which involves using a small fiber-optic camera to evaluate the lesion.

There is no single physical exam test to diagnose a SLAP lesion. The aforementioned special tests aid, along with the patient's history, in establishing the diagnosis.

Nonsurgical Interventions

Some nonsurgical interventions are listed below:

- The patient has to decrease those activities that cause the symptoms.
- Anti-inflammatory medication as tolerated is administered.
- Physical therapy to regain range of motion is advised.
- Surgical repair is suggested if all the above fail.

Surgical Intervention

Based on the extent of the injury, the surgeon will either reattach or possibly trim the excess tissue.

Postsurgical Intervention

Ensure that physical therapy (shoulder rehabilitation exercises) is initiated as soon as possible, based on the type of injury sustained. Typically, patients need to rest for a month and then increase activities as tolerated.

In summary, this lesion is not very common, but once it occurs, it can be very debilitating, affecting activities of daily living and participation in sports. Prevention is the key. The athlete is advised to start slowly and increase the activity level gradually as tolerated. At the first sign of the symptoms discussed, a visit to the physician is recommended.

Athletes with this shoulder injury should refrain from participation in sports pending clearance from their physician to prevent further damage to the shoulder.

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See also Musculoskeletal Tests, Shoulder; Shoulder Injuries; Shoulder Injuries, Surgery for

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Surfing, Injuries in

Surfboard riding (surfing) is a sport practiced in coastal areas around the world. For the purposes of this entry, surfing will describe the sport whereby the participant engages waves in the water while standing on a surfboard. This is in contradistinction to many other wave and board sports, ranging from bodysurfing to boogie boarding to kite boarding and other activities.

Surfing is a sport that is practiced in increasing numbers: It is estimated that 1.7 million people in the United States and more than 18 million people worldwide participate in this sport.

Overview of the Sport

The sport began centuries ago in the South Pacific. Westerners first encountered surfing in the 18th century when exploring the Pacific islands. In Hawaii, for instance, it was considered the sport of the royalty. It is reported that missionaries actively suppressed the practice in the European settlements, and the sport continued to decline until the 20th century.

The resurgence of the sport in the 20th century began with Duke Kahanamoku, a Hawaiian Olympic swimmer who performed surfing exhibitions in America and Australia. In the mid 20th century, a nexus of factors contributed to the rise in the popularity of surfing: Advances in surfboard design allowed for mass production of lighter-weight boards using materials such as balsa wood, foam, and fiberglass, and cultural changes, including increased emigration to the warm coastal zones and the rise of a "beach culture," saw markedly increased numbers of people take up the sport. By the turn of the millennia, surfing had grown into a worldwide participatory sport and a big business: 195 million surfboards were sold worldwide in 1995.

Surfing is primarily a recreational sport, though worldwide there are increasing numbers of competitions and attempts at forming surfing associations. The Association of Surfing Professionals (ASP) organizes regular competitions at the professional level. On the local level, there are an ever-increasing number of amateur and school-based competitions. There are contests also that center on "big-wave" riding, with its inherently higher risk of injury; "Mavericks" in Northern California is perhaps the most famous.

The vast majority of participants, however, will mostly take to the water to have fun and will be under no formal regulations or requirements. On some level, all that is needed to participate in the sport is a board and access to waves. Surfers can be of all ages and both genders, though many authors have noted a preponderance of male surfers: In many studies, the ratio of male to female surfers is on the order of 9:1. This too, as in many sports, appears to be changing, and increasing numbers of women are taking up the sport.

A final note should be made about the distinct difference between *longboards* and *shortboards,* which represent the two principal types of boards a surfer might use. Each uses a slightly different style. Longboards are typically greater than 2.2 meters (m) in length and are characterized by a rounded nose with one to three fins. They are marked by being more buoyant, more stable, and less maneuverable than shortboards. Shortboards are 2.2 m or less in length, typically have a pointed nose and three fins, and are very light. Shortboard riders often aim to perform more dynamic moves on the waves, including cutbacks, 360° rotations, and "aerials" (launching into the air off a wave). Neophyte surfers typically learn on longboards; more expert surfers may choose either type of board, depending on the wave conditions and the goals for any particular surf session.

Most boards also include a leash attached to the surfer's ankle, enabling the surfer and his or her board to be in somewhat close proximity after the inevitable wipeout. Using a leash can also prevent one's board from flying into a neighbor on the water, but the device is not without risk, as will be discussed subsequently.

Demands of the Sport

Real-time analysis has found that surfing is an intermittent sport in which paddling accounts for

A surfer wiping out on Hawaii's Bonzai Pipeline. Surfers are prone to injuries related to environmental exposure as well as acute and repetitive stress injuries.

Source: Jan Tyler/iStockphoto.

50% of the activity and waiting for suitable waves while on the board accounts for another 40%; only 5% to 10% of a surf session is actually spent riding a wave. A large amount of the time in the water, then, a surfer will be paddling prone, with his or her back in hyperextension. When "catching a wave," the surfer will then pop up from a prone to a standing position as he or she descends the face of the wave. Executing subsequent maneuvers, ranging from turning at the bottom of the wave to cutting back up the face of the wave to still more (see www.riptionary.com), will require an extraordinary amount of balance and lower body strength.

The unique demands of the sport require that the surfer possess a decent amount of both aerobic and anaerobic fitness. Paddling out to a surf break and negotiating obstacles (ranging from waves to other surfers) requires high levels of upper body strength, especially in the shoulders, and a good deal of upper body fitness. Studies have shown that elite surfers will have peak oxygen uptake characteristics similar to other elite upper body athletes (e.g., kayakers) and anaerobic power capacities similar to rugby players.

Injuries

Surfers are prone to *acute* injuries; chronic, repetitive motion injuries; and injuries related to environmental exposure. The reported injury rate has been 4 per 1,000 hours of play (comparatively, the injury rate among National Collegiate Athletic Association [NCAA] male soccer players is 18 per 1,000 hours of play). Some caution should be used, however, in interpreting these numbers, as the novice participation rate in the sport is ever increasing and it is likely that the studies reflect some underreporting in injury rates. Likewise, injuries are thought to be on the rise with increased crowding in the water leading to more likely collisions between surfers and other people and objects in the water. Overall, however, surfing appears to be a relatively safe activity.

Soft tissue injuries such as contusions and abrasions are among the most frequent injuries a surfer will sustain, with lacerations being the most common, representing 42% of all acute injuries. Injury surveillance studies note that the surfer's face is the most common area for lacerations, and the culprit is typically the surfer's own board. The board leash is implicated in many of these injuries, as the board can easily recoil into the surfer after a wipeout. Minor wounds are typically treated in the usual manner, with particular attention to thorough irrigation and exploration to remove retained foreign bodies. Major wounds oftentimes require consideration of delayed primary closure and/or prophylaxis against infection from common marine pathogens, including *Vibrio* species—fluoroquinolones or third-generation cephalosporins. Ruling out an associated open fracture is also important, and consideration should be given to appropriate imaging if indicated.

There are a great number of musculoskeletal conditions that can plague the surfer. Given the great amount of paddling a surfer will do, it is not surprising that shoulder problems are common. Overuse injuries such as impingement, rotator cuff tendinitis, and acquired acromioclavicular (AC) joint arthropathies are seen. Acute injuries, such as shoulder dislocations, can give rise to acquired instability and labral pathology. The back knee of the surfer (farthest away from the board's nose) is another joint at risk, as many maneuvers will require the surfer to put this knee into acute valgus position, courting potential disaster to the medial collateral ligament and meniscus as well as the anterior cruciate ligament (ACL). The front knee, conversely, is oftentimes at risk of hyperextension injuries, including hamstring strains.

Paddling requires the surfer to be in a hyperextended position for prolonged periods of time, and this leads to some special injury patterns. Simple low back strain is common. The typical surfer needs to pay special attention to core and abdominal strength, as well as flexibility of the back, hamstrings, and hip flexors. Over time, isometric hyperextension, repetitive torquing of the lower spine from various maneuvers, and acquired trauma from waves and the like can give rise to spondylolysis and spondylolisthesis. Older surfers often develop degenerative disk disease of the lumbosacral spine.

A unique condition is being increasingly reported in novice surfers: *surfer's myelopathy*. A nontraumatic, usually temporary, paraplegia can develop and appears to be the result of ischemia to the lower thoracic spinal cord caused by the prolonged hyperextension seen when board paddling. Signs and symptoms include lower extremity sensory changes and weakness, new-onset mid to low back pain, and urinary retention. Treatment protocols are still being developed.

Cervical spine trauma is a possibility, as waves can break on reefs, on sand bars, and near fixed objects such as jetties. Aging surfers with preexisting, acquired spondylolysis are at particular risk of catastrophic injury from forced neck hyperextension.

Head, eyes, ears, nose, and throat (HEENT) issues are seen frequently in surfers. Recoil of a board, for instance, can cause much more damage than lacerations. Concussions, oral and maxillofacial injuries, orbital fractures, ruptured globes, and a detached retina have all been seen as a result of trauma sustained during surfing. There is an increasing awareness of the danger to the eye courted by surfers, and there are increasing attempts to encourage use of eye protection when in the surf.

Less severe, but oftentimes more troubling to the surfers because of their frequency and ability to keep them out of the water, are acute conditions such as otitis externa, ruptured tympanic membrane, and the chronic condition known as "surfer's ear." Otitis externa should be treated in the usual manner. Prophylaxis can be achieved by using ear plugs and after a surf session instilling a 50:50 mix of white vinegar and alcohol. A ruptured tympanic membrane will usually spontaneously heal after approximately 2 weeks, and the surfer should not be allowed to enter the water until that time. Close follow-up is indicated.

Surfer's ear is a term applied to external auditory exostoses that develop over years of participation in the sport. The external ear canal develops a reactive hyperemia on exposure to water, particularly cold water; chronically, the reaction can proceed to development of exostoses in the canal. These growths can cause a progressive, albeit reversible, obstructive hearing loss and can also predispose the surfer to recurrent external ear infections. Studies have demonstrated that the longer one surfs and the more the surfer exposes himself or herself to cold water, the higher the chance of developing this condition: A male surfer who has surfed regularly for more than 20 years has a one in two chance of developing this condition. Treatment is surgical, but this is an eminently preventable condition with regular use of ear plugs.

Finally, this is a sport in which the environment affects the participant in a much more direct and significant way than seen in many other sports. Surfers are at high risk for acute and chronic sun damage to the skin and eyes: Sunburns, skin cancers, actinic conjunctivitis, and pterygiums are seen frequently in the surfing population. As ever, prevention can play a significant role here. Regular and frequent use of a waterproof sunblock is encouraged. There are also commercial eye protection devices that can provide ultraviolet protection as well as protection against trauma; it remains to be seen how often a surfer might use these.

The "big risks" of being in marine environments, such as shark attacks, get a lot of media attention but are very rare. More common are marine envenomations from coelenterates (jellyfish and related organisms), stingrays, sea urchins, and coral reef lacerations. Treatment for these injuries can be found in the recommended readings. Drowning, as in all water sports, is a risk every surfer takes. The best prevention of this catastrophe is prudence. At all times, the surfer should be aware of environmental conditions, avoid concomitant use of mind-altering substances, surf with a "buddy," and avoid surfing if conditions exceed one's ability.

James Patrick Macdonald

See also Ear Injuries; Friction Injuries to the Skin; Outdoor Athlete; Sunburn and Skin Cancers

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Swimming, Injuries in

Swimming is a highly popular sport involving participants of all ages, various body types, and both genders. People take up the sport for leisure and cardiovascular exercise as well as competition. Swimming can be broadly defined as nearly any movement an individual can do in the water. For the purposes of this entry, the concept of *swimming* will be restricted to what is generally considered supervised lap swimming, using defined stroke techniques. There will also be some discussion of open-water swimming, which is a sport pursued in its own right as well as one component of the triathlon event. (Serious and catastrophic cervical spine injuries that may occur when diving into a pool or open water are not discussed in this entry.)

Most swimmers will train in pools, which are typically set up as "short course" (25 meters [m] in length) or "long course" (50 m in length). Open-water swimming refers to swimming in lakes, ocean, or other bodies of water; the distances involved here sometimes are measured in miles.

The four principal competitive strokes are the front crawl, breaststroke, backstroke, and butterfly. Over the years, there have been some modifications in the forms, techniques, and regulations pertaining to each stroke. The recommended reading section gives a fuller treatment of each stroke. The term *freestyle* is sometimes used synonymously with the front crawl but more accurately means *any style* for individual distances and *any style but breaststroke, butterfly, and backstroke* for the medley events.

Some authors have argued that swimming possibly provides the most balanced form of exercise. Use of different strokes and variation in technique emphasize at different times the upper extremities and the lower extremities. The swimmer can develop endurance, power, agility, and coordination in the entire body. Swimmers attest to the psychological benefits of the sport. In competition, the athlete can perform both as an individual and as a team member, especially in relay events. The sport can, therefore, appeal both to the loner and to those who socialize. Equipment is minimal. Perhaps, the only drawbacks are the obvious need for access to water and the fact that swimming does not involve full-body weight-bearing impact on the skeleton and hence does not enhance bone density.

Swimming is particularly suited to the developing athlete. Acquiring good fundamentals as a youth can lead to mastering an activity that can be carried forth through one's geriatric years. Studies have demonstrated an exceptionally low acute injury rate. Compared with age-matched nonathlete controls of ages 13 to 19, young swimmers have been found to demonstrate enhanced physical, cardiovascular, mental, and social skills.

A final note should be made about equipment. At the most basic level, a swimsuit is all that is needed. Goggles are typically worn to prevent irritation to the eyes from the chlorine often used to clean pools. There are many different devices used by coaches and athletes for stroke work or overload training. The most common are fins, kickboards, pull buoys (a flotation device put between the legs of the swimmer to move without the use of the legs), and hand paddles. At times, these devices can be involved both in the development and in the treatment of injuries, as is discussed below.

Injury Patterns

General Principles

From an orthopedic perspective, overuse conditions predominate as the type of injuries that swimmers will encounter. It is estimated that the average collegiate swimmer performs 1 to 2 million strokes annually with each arm. Periodicity is sometimes less than ideal: Swimming for many participants is a year-round activity, often involving two practice sessions daily. During these sessions, the athlete may swim extraordinary distances: 10,000 to 15,000 m/day of training is not uncommon at the college level. Additionally, the swimmer may engage in "dry-land" weight training and stretching activities, some of which may actually increase the risk of injury.

Besides overuse, technique can also expose the swimmer to injury. Poor stroke mechanics applied in the front crawl are frequently implicated in the development of shoulder problems. The arm pull in the butterfly stroke and breaststroke, and less frequently the freestyle, can cause stress syndromes of the elbow. The breaststroke, with its specialized kick, can cause a similar stress injury to the knee. Though swimming, especially the front crawl, is often an exercise prescribed for the treatment of back pain, the unique movements of some strokes expose the back to some risk. The breaststroke can induce an exaggerated lordotic posture of the lower back, causing extension-based back problems. The butterfly stroke has been implicated in the development and exacerbation of Scheuermann kyphosis.

Given this involvement of overuse and technique, most orthopedic issues seen in swimmers, after an accurate diagnosis has been made, will respond to rest, targeted physical therapy, and attention to appropriate modification of technique.

As a final note, though management of most swimming injuries will require rest, it is important to minimize the swimmer's time out of the water not only to avoid deconditioning but also to enhance compliance. Intelligent use of other strokes and/or equipment can often allow the swimmer to rest the affected body part while still being in the pool.

Shoulder

The upper extremity is frequently injured as a result of overuse in the competitive swimmer, and of the involved joints, the shoulder is, far and away, the most frequently implicated: It has been reported that 90% of the complaints by swimmers that bring them to a doctor are related to shoulder problems.

Swimmer's shoulder is the most common injury seen. This is an inflammatory condition of the supraspinatus and biceps tendons, resulting from overuse, glenohumeral instability, and, at times, improper stroke technique. All three contributory causes should be addressed in the diagnosis and treatment of the condition.

The glenohumeral instability seen in this condition is often acquired. Many elite swimmers have inherent ligamentous laxity and often will have multidirectional shoulder instability. However, all swimmers will overdevelop the adductor and internal rotator muscles of the shoulder simply by performing their stroke. The relative weakness of the external rotators and scapular stabilizers of the shoulder results in a humeral head that can migrate anteriorly and superiorly during the front crawl and also the butterfly stroke. Related to overuse, technique, training style (e.g., pull buoys, paddles), and acquired muscular imbalances, the adductors and internal rotators become overdeveloped and the anterior capsule more lax.

The patient will typically present with diffuse shoulder pain and aching that have gradually increased with training. At times, the pain will be localized to the posterior or anterior shoulder, corresponding to the location of the supraspinatus and the biceps tendon. Physical examination generally reveals weakness of the rotator cuff muscles. Maneuvers designed to assess impingement, including the Neer and Hawkins tests, will oftentimes be positive. So too, maneuvers assessing the biceps tendon, such as the Speed and Yergason tests, can be positive. The patient will oftentimes have generalized ligamentous laxity, and the shoulder will often be found to be exceptionally lax or even unstable; occasionally, anterior apprehension and anterior subluxation of the shoulder can be seen on exam.

Imaging is usually not indicated in swimmer's shoulder and should be reserved for recalcitrant cases, atypical presentations, or at times initially for the older swimmer.

Treatment will begin with relative rest. Typically, the front crawl will need to be avoided. If the patient's symptoms are unilateral, they may be allowed to do the one-armed butterfly stroke. Breaststroke and backstrokes are often forgiving. Kick drills can be done, but kick boards (which tend to forward flex the shoulder and aggravate impingement) should be avoided. Paddles and pull buoys, which often contribute to the problem in the first place, should be entirely avoided.

A coach should look at the swimmer's mechanics. In a properly performed front crawl technique, the elbow remains well above the hand when the arm is out of the water, during the recovery phase of the stroke, and as the hand enters the water, during the "catch" phase. Swimmers who allow their elbows to drop may irritate the rotator cuff muscles.

Rehabilitation should focus on stretching the posterior capsule; strengthening the scapular stabilizers as well as the rotator cuff muscles, especially the infraspinatus and teres minor; and occasionally addressing core stability weakness. Exercises in the initial phase should exclude movements that abduct or flex the shoulder beyond 90°.

True rotator cuff tendinitis and bicipital tendinitis can be seen and should be treated accordingly. Degenerative diseases of the shoulder are typically seen in masters-level swimmers. Acromioclavicular and glenohumeral joint arthritis are found in this population, as well as true bony impingement. The geriatric patient may present with a frank, degenerative tear of the rotator cuff tendon. The clinician should have a low threshold for obtaining plain-film radiography, and possibly advanced imaging, in swimmers above the age of 35 years. Treatment would initially be similar to that described above for swimmer's shoulder, but in degenerative cases, more aggressive treatment, including referral to orthopedic surgery, is often indicated. The details of this treatment are beyond the scope of this entry and are found elsewhere in this encyclopedia.

Knee

Knee injuries in swimmers are almost exclusively seen in breaststrokers and are related to the use of the whip kick in that stroke. A study reviewing knee pain in breaststrokers demonstrated an association between more frequent knee pain and higher age of the swimmer, increasing years of competition, increase in training distance, and decrease in warm-up. Nevertheless, the very biomechanics of the stroke can put any breaststroker at risk.

The whip kick itself does not use the flexion and extension patterns seen in the flutter and butterfly kicks, which are natural motions for the knee joint. Rather, the motion applies a significant valgus strain to the joint, resulting in three recognized injury patterns: (1) medial collateral ligament (MCL) stress syndrome, (2) patellofemoral syndrome (PTFS), and (3) medial synovial plica syndrome.

The clinician can diagnose MCL stress syndrome by taking a careful history. Pain is typically activity related, insidious in onset, and localized at the medial aspect of the knee. Palpation over the course of the MCL, from the adductor tubercle of the femur to the insertion on the medial tibia, typically reveals tenderness. Applying a valgus stress to the knee with the leg in external rotation causes pain. The clinical findings of PTFS present no differently in the swimmer than in other athletes. Medial synovial plica syndrome typically presents with complaints of pain experienced at the extension phase of the whip kick. The medial synovial plica is a fold of synovium, which can become irritated; physical examination can frequently reveal a tender, thickened plica crossing the medial femoral condyle. There is typically no pain with a valgus stress.

Treatment for these conditions is typically one of relative rest and the use of anti-inflammatory medications. Occasionally, training can continue by performing strokes other than the breaststroke but only if the swimmer is painfree. Ice and nonsteroidal anti-inflammatory drugs (NSAIDs) are helpful in controlling the inflammation. Addressing stroke mechanics is imperative for all three conditions.

MCL stress syndrome by its nature can persist and can be difficult to treat; it occasionally necessitates changing over to other strokes indefinitely. PTFS is amenable to classic physical therapy techniques addressing patellar tracking. Medial plicae can cause persistent trouble and may require steroid injections or surgical excision.

Foot and Ankle

The most common injury seen in swimmers is tendinitis of the extensor tendons at the extensor retinaculum of the dorsal foot. In this area, the tendons of the extrinsic foot dorsiflexors are encased in their tendon sheaths and are prone to irritation.

In both the flutter kick of the front crawl and the dolphin kick of the butterfly stroke, the foot and ankle are carried through extreme plantarflexion back to neutral position, setting up a situation where the extensor tendons can become inflamed.

Diagnosis is usually straightforward. There can be swelling and tenderness over the extensor retinaculum. Passive range of motion of the ankle typically elicits crepitus in the tendons; having the patient dorsiflex the foot against resistance can evoke pain.

Treatment involves the use of modalities such as ice and ultrasound; NSAIDs may be used to help decrease the inflammation as well. Relative rest is indicated. The patient may swim using a pull buoy to avoid kicking. A program of gentle, pre-exercise stretching of the extensor tendons should commence. Return to full swimming with normal kicking should progress in a graduated fashion.

Elbow

Stress syndromes of the elbow are seen in the arm pull, particularly in the butterfly strokes and breaststrokes. Occasionally, lateral epicondylitis can be seen. Treatment would include relative rest, attention to stroke mechanics, and eccentric strengthening of the wrist extensors.

Wrist and Hand

Less commonly, de Quervain tenosynovitis can be seen, especially in the older swimmer. Frequently, the inciting cause is poor technique. Diagnosis and treatment are the same as in other athletes with these symptoms. Thoracic outlet syndrome, discussed elsewhere in this text, is occasionally seen in swimmers as well. Presenting complaints include paresthesias radiating down the shoulder and arm into the hand, especially over the small finger, complaints of weakness and aching of the arm, and weakness of the hand grip.

Back

As discussed previously, extension-based back pain, including mechanical low back stress, spondylolysis, and spondylolisthesis, can be seen in the breaststroke and, occasionally, the butterfly stroke, especially when the latter stroke is poorly executed. Scheuermann kyphosis can be seen in the butterfly stroke specialist. Degenerative disease of the cervical spine is occasionally seen in the masters-level swimmer. The clinician should attempt to make a precise and accurate diagnosis and treat accordingly. The specifics of treatment for each condition are elaborated elsewhere in this encyclopedia.

Medical (Nonorthopedic) Issues

Asthma is not infrequently seen in swimmers. Some of those suffering from asthma have positively embraced swimming and have noticed that the warm, humid environment of an indoor pool makes their breathing easier. Others will find that an enclosed environment with chlorine fumes may exacerbate the problem. Clinicians caring for swimmers should be conversant with the management of asthma.

Skin and hair problems are seen in swimmers. Viruses and fungi can be transmitted from pool decks and locker room floors, giving rise to plantar warts and athlete's foot. As ever, prevention (including in this case the use of sandals) beats treatment, which would be done in the usual fashion. Swimmers occasionally will shave their bodies prior to meets, giving rise to folliculitis. Pseudomonas as well as *Staphylococcus* infections are often implicated. Topical antibiotics may be used, but occasionally, oral antibiotics will be required for severe or resistant cases. Chlorine and other chemicals used in the treatment of pool water can affect a swimmer's hair, giving rise to color changes. The most effective treatment is, again, prevention: the use of swim caps and frequent shampooing.

Not surprisingly, otitis externa is seen commonly in swimmers. Prevention is best achieved by wearing a tight-fitting swim cap that covers the ears. Alternatively, commercial products containing vinegar and alcohol can be instilled in the ears after swimming to "dry" the ear canal out. If the patient becomes symptomatic, the use of prescription antibiotic/antifungal/anti-inflammatory eardrops and a period of scrupulous avoidance of water are recommended. Out-of-pool time can last as long as 7 days, but if the patient is asymptomatic after 2 to 3 days, he or she may be allowed back in the pool while continuing treatment.

Eating Disorders

Though more definite data are needed, swimming is recognized, along with cross-country running, gymnastics, and diving, as one of the sports in which female athletes especially will have higher rates of eating disorders, including bulimia, anorexia, and other disordered eating behaviors. In one study, 15% of college female athletes had some form of subclinical eating disorder; this is a higher rate than is seen in the general population. Olympic swimmer Dara Torres has publicly shared her struggle with bulimia as a young swimmer. Swimmers often will pursue disordered eating behaviors in the misguided belief that they will help them swim faster or in pursuit of a more idealized body image. Since a principal hallmark of these illnesses is denial, it is incumbent on coaches, trainers, clinicians, and parents to have a high degree of suspicion when addressing the problem in their athletes.

Drowning

As with any event associated with water, swimming exposes the athlete to the risks of drowning. The danger is greater for the open-water swimmer. It is recommended that an athlete always train in a supervised pool setting (i.e., with a coach or lifeguard) or train with a "buddy," either in the pool or in the open water.

James Patrick Macdonald

See also Asthma; Female Athlete Triad; Fungal Skin Infections and Parasitic Infestations; Scheuermann Kyphosis; Shoulder Instability

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T

Tailbone (Coccyx) Injuries

The tailbone, or *coccyx,* projects below the pelvic bone, first curving backward and then curving forward at the tip. There are three to five segments dividing the coccyx. Between these segments are joints, much like those seen between the bones of the spine. However, these may be fused in the coccyx. Injuries to the region of the coccyx can result when the fused joints are repeatedly forced out of their normal positions with regular activities, causing inflammation of the tissues surrounding it.

When a person is sitting, the coccyx, along with the two prominent regions of the pelvic bone, called the *ischial tuberosities*, bears the weight. When a person leans back in a seated position, the weight load on the coccyx increases. The birth canal in women is defined posteriorly by the coccyx. The muscles responsible for the voluntary control of bowel movement attach onto the coccyx.

Mechanisms of Injury

The coccyx is easily exposed to blunt trauma. A fall backward into a seated position is the most common cause of injury. Direct trauma can occur from a kick, using a trampoline, falling from a horse, or a skiing mishap, causing the coccyx to be bruised, broken, or dislocated. Poor posture while sitting for a prolonged period of time, such as while traveling in a car or plane, or sitting on a hard surface can result in trauma as well. Injuries can be encountered as a result of repetitive pressure on the coccyx, as in cycling and rowing. Prolonged sitting, even on a soft seat (i.e., office workers and students), has been documented on patient history as a reason for coccyx tenderness. Anal intercourse has been implicated in injury to the coccyx.

Because the birth canal is bounded by the coccyx at the back, pressure exerted during childbirth can instigate injury. The coccyx is literally "in the way" during childbirth. The resulting pain can involve the muscles used in bowel movement as well as the muscles of the buttocks.

Signs and Symptoms

The coccyx will be painful and often markedly tender, especially while sitting in a leaning-back position. Pain may also be felt on standing from a seated position, with bowel movements, and during sexual intercourse. The adjacent structures may not be tender.

It is important that spinal and pelvic conditions are ruled out, as these may cause pain over the coccyx area. Disk disease may be misinterpreted as injury to the coccyx. However, the coccyx will usually not be tender if only the spine is involved, and the examiner should consider other diagnoses.

Other possible causes of pain that may be misinterpreted as injury to the coccyx include the following:

- Pain of the pyriformis muscles
- Injury to the pudendal nerve, especially in bikers who sit for prolonged periods of time
- Pilonidal cysts, Tarlov cysts, or meningeal cysts

- Obesity, which leads to excess pressure on the coccyx when sitting
- A bursitis-like condition in slim people, who have little fat padding in their buttocks, causing the tip of the coccyx to constantly rub against the subcutaneous tissues

A rectal and pelvic examination may also be performed to rule out other conditions.

Imaging

Management of the condition often does not change with findings on X-rays, so there is often no need to obtain them, unless the examiner finds the results of a physical examination to be inconclusive. X-rays usually include a lateral view of the coccyx. Lateral views may be taken while standing and sitting to measure coccygeal mobility. X-rays of the coccyx reveal four different types. Most people have a Type I coccyx, which curves slightly forward. The Type II coccyx curves forward, with its tip almost pointing straight forward. The Type III coccyx sharply angles to the front. The Type IV coccyx shows movement of the usually fixed joints within the sacrum or within the coccyx itself. The coccyx can move up to 22° when a person repositions from standing to sitting. Subtle backward movement of the coccyx can be noted by taking a sitting lateral X-ray and comparing it with a standing film to check the amount of translation. Mild displacement is defined as more than 25% movement of the coccyx from the standing to the sitting view. In dynamic X-ray imaging, abnormally increased movement of the coccyx is defined as more than 25° of forward movement on a lateral X-ray. Measurement of the angle formed between the first and last segments of the coccyx can provide an objective measurement of forward movement of the coccyx. Computed tomography (CT) scans and magnetic resonance imaging (MRI) scans often do not add significant information to standing and sitting dynamic views. However, an MRI can be helpful if a tumor or infection is suspected.

Repetitive stretching of the surrounding ligaments and muscles attached to the coccyx may result in inflammation of these tissues, causing pain and soreness when sitting or with straining. Continued movement may prevent healing of this injury, resulting in further damage and perpetuation of the cycle. In such cases, X-rays and MRI scans may be required. Abnormal movement of the coccyx may be due to partial dislocation, and this may be noted on patient X-rays taken in the standing and sitting positions.

Treatment

Relief from pain caused by coccyx injuries may take weeks or even months. Pain in the coccyx after an injury may become chronic in some patients. Referral to a specialist is usually unnecessary; however, referral to pain specialists, medication, rehabilitation, anesthesiology, or orthopedic surgery may be needed for patients who develop chronic pain in the coccyx. Pain due to trauma to the coccyx usually resolves on its own with protection of the bone from further injury. Pain medications, heat, or ice can bring relief. Leaning forward while sitting protects the coccyx, as weight is mainly borne on the ischial tuberosities with this position. Weight may be distributed away from the coccyx by using "doughnut" cushions or pillows with a central hole. "Wedge" cushions or pillows with a wedge-shaped section cut out of the back may also be used. These may be purchased or made quite easily. Hot or cold compresses appear to work in selective cases. Pain relief may be obtained with nonsteroidal anti-inflammatory medications. Narcotic painkillers should be avoided unless the pain is severe.

Specialists may inject a local anesthetic, with or without corticosteroids, using X-rays for guidance. Positive results have been noted in some studies with this treatment, although pain relief has been shown to last only for a few weeks.

Specialists are able to manipulate the coccyx through the rectum. The purposes of this treatment are to massage the muscles attached to the coccyx, as they are often spasmodic, or to mobilize the fascia surrounding the coccyx. Several studies have shown modest improvement with these manipulation techniques.

In chronic cases, antidepressants or antiepileptic medications may be helpful. Acupuncture may be a reasonable option, although it is not known whether modalities such as ultrasound or transcutaneous nerve stimulation actually work to relieve pain due to coccyx injury.

Surgical removal of the coccyx is the last resort. Pain relief obtained after this procedure has been studied, with varied results, mostly leading to the conclusion that surgery does provide pain relief for most patients. However, it is important to note that complications such as infection, injury to the rectum, and problems with bowel movement may occur following this procedure.

George Guntur Pujalte

See also Hip, Pelvis, and Groin Injuries; Lower Back Contusion; Sports Injuries, Acute

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Taping

The application of tape in sports plays a significant role in today's athletic performance arena. In professional or collegiate sports, the Olympic Games, or local youth league games, a wide array of taping as well as bracing applications are used to enable athletes to enhance their performance, correct minor functional abnormalities, and participate in sports while recovering from injury.

In 1895, what is now known as the *closed basket weave* was described by V. P. Gibney. This original ankle taping was first known by the name "Gibney boot" and was an imitation of a procedure performed by army medics in England. Since that first taping application, not only has the practice of taping expanded dramatically, but also the taping and bracing industry has undergone considerable growth; currently, there are more than 10 major tape manufacturers, providing a wide variety of padding, braces, adhesives, and tapes for use by practitioners.

In the field of sports medicine, taping techniques are currently taught in a variety of courses for specialists. For Certified Athletic Trainers, taping and bracing is a curriculum requirement mandated by the Board of Certification. Although it is not a mandatory class for those seeking certification as a Licensed Physical Therapist, there are various continuing education and undergraduate elective courses that candidates can take to gain this knowledge and skill. A sound understanding of the mechanisms of injury, detailed knowledge of anatomy, and continuous practice of effective methods are the keys to learning how to tape and brace correctly. Once the basic skills are learned, they can then be adapted to a variety of real-life situations and applications.

Appendix A provides detailed information on the materials and clear, step-by-step explanations, accompanied by photographs, of the taping and wrapping methods and techniques most commonly used by specialists.

Arthur Horne and Cheryl Blauth

See also Ankle Instability; Ankle Instability, Chronic; Athletic Trainers; Bracing; Knee Injuries

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Target Heart Rate

The premise of aerobic exercise is to exercise at an intensity that will challenge the aerobic energy system while minimizing the risks of adverse health consequences. One way of remaining cognizant of the intensity at which one is exercising is to monitor the heart rate. Heart rate increases in a predictable fashion as exercise intensity increases from light to moderate to vigorous. There is a linear relationship between the heart rate and exercise intensity, and the heart rate is generally accepted as an accurate means of assessing and monitoring relative exercise intensity.

This relationship is a function of the heart's greater demand to pump blood and oxygen to skeletal muscle at higher intensities. The other parameter that increases the heart's ability to pump blood is an increase in "stroke volume," or the volume of blood pumped during each heartbeat. The extent to which these parameters increase is primarily determined by training status: Untrained individuals rely more on increasing the heart rate, whereas trained athletes have a greater ability to increase stroke volume and thus rely less on heart rate at the same exercise intensity.

Individual athletes have a maximum heart rate often predicted by the simple equation "220 minus age," which reflects the physiological ceiling below which the system operates. Younger athletes tend to have higher maximum heart rates; this maximum declines with age. There is also a difference between the sexes; the equation described above has an error of ±10 beats/minute.

Exercising at intensities close to maximum heart rate has theoretical risks. There is slightly increased incidence of adverse coronary events when the heart is maximally challenged, likely a consequence of relative ischemia (or lack of oxygen supply) to areas of heart muscle, particularly in male athletes younger than 35 years. This ischemia can result in a myocardial infarction or an abnormal heart rhythm, such as ventricular tachycardia, both of which can result in sudden death. This risk is multifactorial and slight and does not preclude athletes around the world from competing at intensities close to the maximum. However, when developing guidelines for the general population to perform aerobic exercise, attention has been focused on encouraging exercise at intensities <85% of the maximum.

Determining the exercise intensity, and hence heart rate, most effective for achieving one's exercise goals depends on what those goals are. Aerobic exercise at lower (light) intensities tends to rely on the oxidation of fatty acids for fuel and hence is a suitable intensity for those attempting to achieve weight loss by "burning" adipose tissue or fat stores.

Athletes hoping to improve aerobic performance seek to optimally challenge the aerobic system at vigorous intensities close to a zone termed the *anaerobic threshold* or *lactate threshold*. This is the intensity of exercise during which the skeletal muscle involved in the activity transitions from mostly aerobic energy production (using oxygen) to energy production incorporating *anaerobic* systems, which do not need oxygen. Stimulation of the anaerobic system results in lactate production and a rise in blood lactate that can be detected at this threshold. Athletes exercising above the anaerobic threshold develop fatigue more rapidly than when solely relying on their aerobic system. Different strategies can be used to account for this, such as exercising just below the anaerobic threshold or exercising using *interval training*, where an athlete raises his or her exercise intensity above the anaerobic threshold for a short period of time, then dips back below the threshold and continues exercising.

Monitoring the heart rate is easily accomplished by counting the pulse rate, either at the wrist (radial pulse) or at the neck (carotid pulse). Typically, counting the pulse for 15 seconds (and multiplying the total by 4) or 30 seconds (and multiplying the result by 2) is sufficient to obtain an accurate representation of the frequency of beats per minute. The exercise industry also now markets heart rate monitors, usually incorporating a strap that is worn around the chest and a monitor that can be worn at the wrist like a watch.

The ease and low cost of monitoring the heart rate has led to its widespread use as a gauge of relative exercise intensity. Nonetheless, there is some concern regarding the use of heart rate to monitor exercise intensity due to a phenomenon known as *cardiovascular drift*. This phenomenon describes an increase in heart rate with prolonged exercise (greater than 10 minutes) despite the exercise continuing at the same intensity. Cardiovascular drift is likely to be related to the sympathetic nervous system and catecholamine control of the sinus node, where the heartbeat originates. It should be noted that factors other than exercise intensity also affect the heart rate, such as ambient temperature and caffeine intake.

Research has recently focused more on heart rate variability (HRV). Evidence suggests that trained individuals have higher HRV than untrained individuals. Most research shows that during graded exercise, HRV decreases progressively up to moderate intensities, after which it stabilizes. HRV could potentially play a role in the prevention and detection of overtraining. This is currently an area of great research interest, with mixed results reported in the scientific literature. Measuring HRV overnight, in supine sleeping athletes during training camps, has been the most widely reported method. High HRV is associated with high $\dot{V}O_2$max (peak oxygen uptake) values, while it has been found that low HRV is associated with increased mortality, the incidence of new cardiac events, and the risk of sudden cardiac death in asymptomatic patients.

Hamish A. Kerr

See also Overtraining

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Team and Group Dynamics in Sports

Shortly before the 2008 Olympic Games, Mike Krzyzewski, coach of the U.S. men's basketball team, remarked:

> From Athens [where the team finished third] we learned we need time to develop camaraderie. We have to be committed to one another before we can be committed to the team. We're developing a program, not "selecting a team." No one ever "selects a team"; you select people and hope they become a team.

Several weeks later, the U.S. basketball team went on to win the gold medal in Beijing and were noted for the high level of cohesion displayed by the team members during both training and tournament play. Indeed, this example illustrates that while it is clearly important to select the right personnel when creating a team, hard work is required to forge a collection of players into a highly integrated, cohesive, and effective team.

Group Dynamics

The study of *group dynamics* is concerned with understanding the various psychological processes that occur within and between groups. The term *group dynamics* can be traced back to the prominent social and organizational psychologist Kurt Lewin (1890–1947). In the context of group dynamics in sports, considerable attention has been given to identifying the factors that influence team functioning. Among these factors, *cohesion* represents one of the most extensively studied psychological constructs. Cohesion can be thought of as the glue that acts to attract and retain members within groups. The attention given to cohesion among sport psychology researchers is perhaps not surprising given that cohesion has consistently been found to predict team performance, across both highly *interactive* (e.g., soccer) as well as *coacting* (e.g., golf) team sports settings. According to the prominent Canadian sport psychologist Albert Carron, cohesion is multidimensional in nature, consisting of task as well as social dimensions, plus individual-level and group-level orientations. Specifically, cohesion involves the extent to which team members are attracted to the team's task and social activities, as well as the extent to which members perceive the group as a whole to be integrated around these task and social activities. Although research evidence suggests that increasing a team's level of cohesion will lead to increased performance, it is worthy of note that the relationship between cohesion and performance is actually bidirectional in nature. That is, teams also tend to become more cohesive when they perform well.

Role Conflict, Role Ambiguity, and Performance

Beyond performance, cohesion is also influenced by a variety of other factors, such as the types of roles that are performed by team members, the group norms and goals that members establish, the behaviors of those in leadership positions, as well as members' perceptions of their team's capabilities. From the perspective of team roles, athletes are typically expected to perform a range of responsibilities with the team's task-related objectives in mind. When athletes are unclear about their various role responsibilities, they are said to experience role ambiguity. This can lead to greater precompetition anxiety, less satisfaction, and diminished levels of performance. While reducing role ambiguity is vital within sports teams, it is also important to curtail any role conflict that athletes might experience. Role conflict occurs when athletes receive conflicting information and/or expectations about what is required of them. When athletes experience role conflict, they tend to perceive greater role ambiguity and report reduced role-related confidence. Although minimizing role ambiguity and conflict has many benefits for member and team functioning, one must also consider the degree of role acceptance among team members when attempting to maximize performance. Sir Clive Woodward, coach of the 2003 World Cup winning English rugby team, was known to emphasize the importance of selecting and developing a team of "energizers," who bought into the team concept, accepted their prescribed roles, and contributed to team cohesion. If some athletes, who he described as "energy sappers," did not accept their roles and could not be turned into energizers, his recommended strategy was to remove them from the team before they destabilized team chemistry and debilitated the team's level of cohesion.

Team Norms and Group Cohesion

Norms correspond to the accepted standards of behavior that exist for members within teams. Team norms are usually unconnected from the position-specific roles prescribed by a team's coach. These norms are often unwritten and evolve through the course of ongoing group development. While those responsible for developing teams, such as coaches, can allow team norms to evolve naturally, several benefits are associated with formalizing appropriate team norms. This can be accomplished by encouraging team members to contribute to and decide on their own set of expectations for off-field and/or on-field interpersonal engagement (i.e., in the form of an athlete "charter"). Such an approach can foster athlete autonomy and is more likely to result in athletes committing to these rules than if the rules are directly prescribed by a coach or a manager. This, in turn, can facilitate a sense of cohesion among team members. The use of goal-setting strategies has also been found to positively influence team cohesion. In particular, when athletes are involved in setting out their own process- and performance-oriented goals (rather than having these goals prescribed to them), they tend to be more committed to the group's endeavors, thus resulting in improved group integration.

While team cohesion, to a large extent, depends on the quality of interpersonal relations among athletes within a team, the coach can also play a prominent role in fostering group cohesion and a healthy team culture. For example, a growing body of evidence from various organizational settings has found that when leaders display transformational behaviors (see the entry Leadership in Sports), their teams tend to be more cohesive. Transformational leaders motivate followers to go beyond their self-interests for the good of the group and give group members the confidence to exceed minimally accepted standards. In sports teams, when coaches display transformational leadership behaviors, their athletes have been found to display more self-determined forms of motivation (e.g., intrinsic motivation) and also tend to perform better than athletes who are coached by nontransformational leaders.

In the field of sport psychology, a vast amount of research attention has been directed at understanding the determinants and consequences of athletes' self-efficacy beliefs. Self-efficacy refers to a situation-specific form of self-confidence and has been found to be positively related to outcomes such as athlete persistence, effort, and task performance.

While numerous studies have examined the factors that contribute to athletes becoming more efficacious in their *own* abilities to perform specific skills, researchers have also sought to examine the role of collective efficacy beliefs in sports teams. Collective efficacy refers to members' perceptions about their team's conjoint tasks, and in a variety of team sports settings, these beliefs have been found to influence team functioning. Interestingly, collective efficacy has also been found to be both predictive of and predicted by team cohesion. That is, the relationship is reciprocal, whereby team members can become more confident in each other when the team is more cohesive and, conversely, the team can also become more cohesive when members develop confidence in each other.

In light of the various correlates of group cohesion in sports, a burgeoning area of enquiry has centered on developing and testing effective team-building interventions. *Team building* is the umbrella term given to the process of developing cohesion within groups. As the research described above would suggest, team building does not represent a singular unitary process and may involve a range of processes that can be applied to meet the team's specific needs. Team-building interventions in sports tend to be either *direct* or *indirect* in nature. With direct interventions, the interventionist (e.g., the sport psychology consultant) intervenes directly with the target population. In comparison, indirect interventions involve the psychologist working with a proxy agent (i.e., a third party), such as a coach, who then leads the intervention with his or her athletes. Although the direct approach has been found to be effective in a variety of team sports settings, one of the benefits of the indirect approach is that coaches are given the requisite skills and are empowered to attend to the team's needs on a day-to-day basis and are not reliant on external personnel in facilitating behavioral change.

In summary, a considerable amount of human behavior in sports settings occurs within groups of one kind or another, and in light of the fact that the psychological processes that occur within groups have been found to predict important personal and group-level outcomes, the study of group dynamics in sports continues to represent a vibrant area of enquiry.

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See also Exercise Addiction/Overactivity Disorders; Imagery and Visualization; Psychological Aspects of Injury and Rehabilitation; Psychological Assessment in Sports; Psychology of the Young Athlete

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Team Physician

The team physician occupies an important position in the public consciousness. News reports about injuries to specific players on sports teams inevitably include interviews with or references to the team physician. In fact, sports physicians—and then team physicians—have enjoyed a high-profile role throughout history.

Historical Perspective

Historians note that battle physicians in ancient times were deemed a necessity. Galen (131–201 CE), a Roman physician of Greek origin, is considered by many to be the epitome of sports medicine practitioners. His voluminous writings reveal that he performed anatomical research and studied physiology, neurology, and wound care. He was appointed physician to the gladiators and was a teacher and a private surgical practitioner. Galen's qualifications to care for athletes and nobles need to be emulated.

Even though there was a marked increase in basic scientific and biological knowledge over the next centuries, there does not appear to have been a similar increase in athletic care and injury reduction in the United States. One possible exception was Edward Hitchcock, MD, who as a school physician at Amherst College in 1854 introduced swimming and gymnastics, emphasized baseball and basketball, and penned a book on athletes and medicine. With the increased popularity of sports participation, the injury rate also escalated. Because severe and often career-ending injuries were occurring so numerously, Harvard University appointed an orthopedic team surgeon in 1890. Other large eastern schools soon followed with similar appointments.

In 1904, the Germans were the first to use the term *sports physician,* and then they proceeded to hold a sports physicians' congress in 1912. This impetus evolved into the Fédération Internationale de Médecine Sportive (FIMS; International Federation of Sports Medicine) in 1933, with the primary goal being to facilitate clinical and scientific research in cooperation with Olympic federations. In 1938, Augustus Thorndike, MD, published a monograph depicting his experiences and knowledge as a team surgeon. His writings, which included much of the scientific knowledge in sports medicine, served as a primary source of pertinent sports medicine information in the 1960s.

A distinct change in sports medicine care of the high school and college athlete occurred when Dr. Jack Hughston (1917–2004) developed team coverage in the early 1950s. He and his orthopedic group and trainers began to "cover" high school football games on Friday night and college games on Saturday. During the week, his crew visited colleges and schools, noted injuries, arranged rehabilitation, and helped decide return to practice and refer, if necessary, back to clinic. This entire program was enacted with the cooperation of the local physician, who was a specialist or generalist, to maintain rapport. This program was not readily accepted until approved by the Georgia State High School Coaches Association. Adjacent states quickly followed this system of sideline and midweek team coverage that persists nationwide to this writing.

In the period after World War II in the United States, there was an exuberance expressed in physical activity and the formation of team sports. Physicians returning home from active duty restarting or starting up a practice often were ushered into a position as a team physician. Most had no sports medical experience, but used good medical knowledge quite successfully. Predominately, these physicians were generalists in the high school and junior college settings. In contrast, the larger colleges, universities, and professional teams tended to select an orthopedist as the primary team physician. While this selection arrangement was transpiring, research and teaching organizations came on the scene such as the American College of Sports Medicine (ACSM), American Orthopaedic Society for Sports Medicine (AOSSM), American Medical Society for Sports Medicine (AMSSM), and the National Athletic Trainers' Association (NATA). Of even greater significance to the practice of sports medicine was the establishment of orthopedic and general sports medicine fellowships. These board-eligible candidates were elected to take an additional year of specialized, sport-centered training under qualified individuals. These mentors used current therapy and ancillary techniques, the most salient of which was the development of the Watanabe arthroscope. This instrument revolutionized the practice of orthopedics and initiated visual understanding of injuries to the knee, shoulder, and elbow.

Even after a fellowship at an accredited institution and after the formal academic process is completed, there are major concerns that must be addressed prior to undertaking the position of a sports medicine physician. No less than for Galen in the ancient world, the essence of practice for Dr. Don O'Donoghue (1917–2004), often referred to as the father of modern sports medicine, was the skillful restoration of the injured patient back to participation status as expeditiously as possible. Times, therapy techniques, and teachings have changed, and certain personal and professional criteria have evolved for both orthopedic and medical sports physicians to contemplate and emulate.

General Criteria

Optimally, to embark successfully into the field of sports medicine as a physician, certain attributes are mandatory. Personal integrity, the athlete's welfare, and the sanctity of the doctor-patient relationship are paramount. Love of sports necessitates considerable time spent at games, practices, and examinations and in the consulting room, so family interaction needs to be facilitated. To function well, the team doctor must possess a working knowledge of a broad range of medical and orthopedic topics and the confidence to make accurate decisions. The measure of a solid team physician is being adept at diagnosing accurately a case of appendicitis as well as an anterior cruciate ligament (ACL) deficiency.

It is imperative that the team physician formulate a program to maintain official standings in state and local academic boards and societies. The physician should join and participate in scientific organizations, cooperate in research protocols, keep abreast of current literature and techniques, and attend sports medicine–related courses and seminars. Since the implementation of Title IX (1974), the team physician must become proficient in caring for the female athlete. Another one of the many important relationships that need to be fostered by the doctor is camaraderie with the head trainer and the staff. Mutual trust and true friendships are to be cultivated.

Another important entity in forming a sound musculoskeletal performance base is the experienced physical therapist. This person needs to be trained in rehabilitation techniques, should be compliant with the wishes of the head trainer and medical personnel, and yet be skilled enough to judge the capacity of the athlete to return to full activity.

The role of the strength coach is integral to this functional group. This person is responsible for personal and team strength improvement and must be certified in the profession. He or she, therefore, knows sports and is capable of enhancing effective playing strength and reducing the risk of injury in the athletes. Strength coaches must respond to the position team coaches and develop programs accordingly.

The head coach of each sport and the subordinates constitute the foundational element in the operational unit that is responsible for caring for the athlete. In addition to mental and physical preparation of the athletes, the head coach determines each athlete's ability, judges what areas need to be improved, and integrates all within the practice schedule. His or her interaction with the players is as important as daily meetings with the other members of the foundational unit (team doctor, trainer, physical therapist, strength coach, and coaches). The coach must communicate freely with the athlete, set a mutual goal, and care for the well-being of the athlete. Additional members of this foundational unit may become involved as the level or caliber of the sport necessitates.

Sports Medicine Physician

Level I

Having complied with state and national stipulations of licensure and satisfactorily completed a sanctioned sports medicine fellowship as an MD or DO in orthopedic or general sports medicine, the team doctor enters into private practice alone or in a small multispecialty group and is legally advertised as a sports medicine physician. In the office, the physician cares for the injuries and illnesses of all caliber of athletes and gratefully accepts insurance. Soon, his or her positive successes bring in parents and then others. The local middle school seeks the doctor's services for all of its sports. When the high school officially recognizes this doctor, then truly he or she is a team physician. The new stipulation requires the team physician to become aligned with radiological, surgical, and medical specialists. To maintain an office practice, a nonwritten agreement with the school officials is mandatory. This official arrangement, which indicates the team physician's scheduled coverage of sports, preparticipation physical examinations, and relationship with high school personnel, is sealed with a handshake. At this stage of the doctor's career, he or she has become the team physician not only of that school but also of the entire area and its active population.

Level II

Officially, the doctor is offered the position of team physician to a fully accredited Division II college in his or her general area with at least 12 different teams. The verbal agreement, witnessed by notables, will allow the doctor to maintain his or her office sports medicine practice, and the school will provide a certified athletic trainer and an office in the school for his or her half-day doctor's visit. It is agreed that the trainer would prepare the athletic field and sidelines and have emergency equipment available. As the sports medicine physician, the doctor would carry a personal sideline kit that contains emergency paraphernalia, oral and injectable medications, the medical history of the players participating, and necessary home and emergency phone numbers. Also, he or she would provide sideline coverage for home football games. For away games, the physician would call his or her counterpart at the other school and secure backup coverage and obtain a hospital contact. The physician would reciprocate when that team plays at his or her school. This new relationship demands more commitment on the sports medicine physician's part. Procedures, routine and pre- and postgame schedules, handling of injuries, and explicit review of emergency protocols and documentation in keeping with National Collegiate Athletic Association (NCAA) rules and regulations are an absolute necessity. It behooves the physician to become a friend, companion, and confidant of the trainer in order to outline rehabilitation and help determine return to play, as well as to be the liaison between coaches, school officials, and parents. When friendship is firmly established, the trainer knows the athletes, their personalities, and their demeanor and is more apt to be aware of abnormal behavior or activity. As noted previously in Level I, establishing consultants in many specialties is deemed necessary in referrals, for preparticipation examinations, and especially with drug testing screening. Any specific problem that is beyond the physician's orthopedic or general medical expertise often requires the athlete, with his or her records, to be examined off campus. Hence, it is an absolute necessity to establish contacts with specialists early in the practice of sports medicine.

Level III

The sports medicine physician accepts a salaried appointment to the state university that holds a membership in a Division I conference. There are eight men's and women's teams with a playoff in each to determine the bowl candidate. Academically, the physician's rank equals that of a full professor and entails comparable perks, including health insurance and prestige, but his or her take-home pay is noticeably less than in office practice. Yet he or she does not have any office expenses since the university provides a fully supplied office, medicines, and travel expenses and allows for state and national license fees. Personal malpractice insurance premiums may be covered in the universities' umbrella policy. Athletic trainers function efficiently as office nurses. Computer and record-keeping facilities are provided and maintained. Since the physician has gratefully experienced and pleasantly succeeded in a sports medicine practice and upheld its qualifications and definitions, this change of venue appears quite inviting to him or her and his or her family.

As in any successful office practice, many functional details persist. An amicable relationship between the trainer, student trainers, physical therapists, and the athlete is mandatory. Duties allocated to the staff with regard to equipment and supplies must be supervised. As in routine office practice, the well-being of the athlete is paramount and requires perfected communication with the individual, parents, and coaches. Previous experience in severe musculoskeletal injuries, surgical cases, diabetic problems, infections, and rashes needs to be supplemented by referrals to competent physicians. On the other hand, newer obligations are to be undertaken. The proper techniques, rules and regulations, and probable injury patterns in each sport must become firsthand knowledge. Why don't women lacrosse players wear masks as men lacrosse players are required to wear? Is the skin eruption on the wrestler similar to that seen on the women gymnast from a floor mat? These and similar problems provoke serious contemplation and research.

The sports medicine physician is indeed fortunate to have an accredited curriculum of athletic training at this university, where athletic training fundamentals are taught and meshed with practiced applications. After the senior year, the student athletic trainer is properly prepared to pass the written, practical, and now computer examinations of the NATA. He or she is obligated to teach this curriculum and partner with the designated department head to determine the course content. These endeavors supplement the one-on-one demonstrations of the diagnostic maneuvers used in musculoskeletal injuries.

A typical week begins with sick call for those athletes who are unable to attend class or those in for recheck to determine their level of function. The history is obtained and documented in the chart by the head trainer. The sports medicine physician's physical examination clarifies the diagnosis and determines the disposition, such as to continue medications and return to class, to arrange for care in the infirmary, or to send to the hospital. In each instance, coaches and parents need to be informed. Parental permission is previously obtained and signed with the athletic department's full documentation on the NCAA identification of eligibility.

Follow-up evaluation of postsurgical care and games/practice injuries is conducted with input from the head trainer, physical therapists, and surgeons. The progress of the rehabilitation protocol is documented, and the coaches are informed. The ultimate outcome of the athlete's situation must be determined— whether he or she is able to return to sports or is to be disqualified for the season, or possibly to file for a "red-shirt" exemption. Orthopedic consultation is obligatory and is welcomed in musculoskeletal problems.

Before the hospital rounds, in consultation with the hospital-based physicians and nurses, the X-rays, computed tomography scans, electrocardiograms, and magnetic resonance imaging scans are reviewed and discussed as a teaching element with the trainers, physical therapist, and staff. This endeavor requires maintaining high-level expertise in radiological disciplines.

Afternoons in season are spent at football practice with the head trainer and his or her staff. The sideline material necessary for routine care of injuries is evaluated, the emergency setup with transportation is alerted and kept in readiness, cell phones are charged, and pertinent numbers are placed in the pockets of trainers. Personnel assignments for the practice are dispensed in concert with the published itinerary for the sanctioned practice. While conversing with the coaches, athletes are scrutinized as to characteristic walk and run, the knowledge of which will be profitable later when returning from injury or surgery. Dehydration, fatigue, and cramps should be urgently treated. Injuries are triaged as to disposition—either to the training room or to the hospital. Those not needing special procedures or consultation are evaluated and tested, and rehabilitation is instituted on the sideline.

Travel with the football team to all away games and to the championships of other sports, when requested by the president of the university, requires considerable preparation with the coaches, trainers, and staff. Consultation and cooperation with the home institution, its facility staff, their physicians, and the hospital for referrals when necessary is the obligation of the team physician. Travel sideline preparations are under the domain of the head trainer but are ratified by the team physician. There is close contact with the players, staff, and medical personnel, so that potential problems can be alleviated early. Team meetings, dining, recreational activities, and bedtime checks all are included in the team physician's itinerary. Occasionally, a member of the traveling academic staff, the athlete's parent, or an eminent supporter may require a visit from the team physician at an inopportune time.

Pregame or practice at home and away involves consideration of each player for play ability, proper taping and protective gear, dehydration prevention, and the issue of medication orally or by injection.

Before spring practice, coordination of and participation in preparticipation screening examinations are absolutely necessary. Usually performed at multiple stations, these screening examinations require many physicians, nurses, trainers, and secretary personnel to record basic information and to review parental signed history forms, as well as technicians to perform blood pressure, visual acuity, and special blood and urine tests. The NCAA manual requires an initial thorough history and an examination that includes cardiovascular and orthopedic evaluations and referral when deemed necessary. Annually, an appraisal of the athletes' records is made, a pertinent history is obtained, and new problems are addressed. A yearly, formal, complete physical exam is not required by the NCAA. Some programs in Division I do obtain more elaborate yearly evaluations.

Recently, it has become a policy for universities to perform an exit evaluation of all athletes, which elaborates the significant medical and surgical history and the final appraisal by the medical and orthopedic team physicians. In the form of a legal document, the head trainer, the team physicians, and the athlete sign a statement indicating the condition of the athlete at the completion of eligibility. Such documentation relieves the university of inappropriate and costly future repercussions.

It is quite common for universities to have high school outreach programs in which trainers and physicians actually attend games of contact sports, as well as hold intraweek injury evaluations. A group of these high schools with established relationships with the university often request assistance in their preparticipation evaluations. As with the university preparticipation examination, a convenient time and location at the university are used. At a scheduled time, a busload of high school athletes with previously signed permission and histories are processed in compliance with the university protocol. The aim of the examination is to enhance medical awareness, determine cardiovascular or medically abnormal conditions, and initiate solutions so that the young athlete can safely continue in the program. Significant findings that require disqualification are documented, the teacher/coach and the patient are informed immediately, and written suggestions are given for a physician's follow-up.

Unfortunately, the perils of narcotics and other banned substances in society permeate into athletics in the university setting. In-house testing of each team is done under the supervision of the team physician. Positive results require evaluation by a certified counselor. In an attempt to obviate this dangerous situation, the NCAA requires each student-athlete to attend talks concerning drug education and the pitfalls of using illegal and forbidden substances.

An ancillary, but extremely important, role for the team physician is related to the weight of the individual athlete. Certain sports require maintaining bulk and strength, while others demand a trim physique. Each athlete needs to be monitored in keeping with the position coach's and the athlete's personal goals. Unauthorized supplements of unknown content taken to gain weight may lead to abnormal symptoms. Excessive weight loss may be indicative of anorexia nervosa or bulimia and may result in myriad physical and mental complications. Initially, private consultation with the athlete may be helpful, but often referrals are indicated. The physician needs to eat in the student cafeteria or its equivalent frequently and notice the display, kind, and array of foods, as well as what foods are usually eaten by the athletes. A working friendship with the school dietitian or the food supervisor may facilitate alteration in the menu and variety. Control of eating problems, as suggested by the team physician and enforced by the head coach's orders, is partially enhanced by making breakfast mandatory for the teams in season.

In the university setting, the woman athlete presents a diverse array of circumstances for the team physician to contemplate. By nature, a woman is hyperelastic in essentially all her joints. With regard to the glenohumeral joint, she may subluxate and spontaneously relocate with minimal labral pathology. Unfortunately, her shoulder subluxation may become recurrent just with walking down the stairs. Rehabilitation may not be completely successful, and subsequently, either open or arthroscopically assisted tightening, because of the texture of the rotator cuff, may be less than optimal even with an appropriate surgical technique.

Hyperelasticity allows women gymnasts to perform outstanding maneuvers that are enjoyed by spectators. However, their popularity leads them to attempt more difficult routines. School and conference competitions encourage more recklessness and higher pyramids. Falls produce bizarre injuries, fractures, and central nervous system mishaps.

The woman athlete, because of a lower center of gravity, anteversion of the hips, and a large quadriceps angle while being quadriceps dominant and with tibial torsion, tends to land after jumping with knees adducted and the trunk upright. This sequence of events may produce patellofemoral symptoms, shin splints, or avulsion of the ACL from its attachment to the femur. Research has shown that with torso (core) strengthening, learning to land bent forward, and better leg muscle control, the incidence of ACL tears can be reduced significantly. It is the team physician's obligation to institute these preventative methods into the training program.

In the era of the resurgence of good health through fitness and sports activity, the team physician must be acutely aware that extremes invariably tend to be manifest and moderation becomes socially unacceptable. The philosophy of being the best in any endeavor and winning at any cost becomes a way of life, initially brought about by the use of performance-enhancing drugs. Drug testing has partially alleviated this problem, but even more sinister elements prevail. The ideology of perfection permeates players, coaches, administrators, and almost all parents. To gain an edge, youngsters are started at a young age to excel in one sport year-round. This methodology is encouraged by specialty coaches, tournament administrators, camps, and television and newspaper coverage. A family vacation may consist of watching one of their youngsters in a competition in another state. Emotionally, family life can suffer, as can musculoskeletal growth and maturation. There is a harmful fallacy that exists that to be bigger, stronger, and faster, as adult athletes are today, the young athlete must become one-dimensional. Forgotten are the facts of heritage, supervised good health, and medical care in infancy and childhood on which organized sports is grounded. Young teenage girls are also involved in this push to excel at a very tender age. The phenomenon is especially noted in gymnastics, cheerleading, racquet sports, swimming/diving, and ball sports. In young girls, overuse or abuse often results in shoulder pathology after repeatedly pitching windmill style for four games in a weekend tournament. Preteen boys who throw excessively at home and in games, even under recent guidelines, are at jeopardy, especially when trying to throw a curve ball instead of developing consistency and a changeup. Orthopedic sports medicine centers are evaluating more and more young boys with medial elbow pathology—formerly seen only in seasoned adult pitchers—that requires surgical intervention. Biomechanical studies have found that faulty mechanics with overpitching and throwing curves in the muscularly immature athlete favors the development of ulnar collateral ligament (UCL) weakness, followed by tearing. Reducing total pitch count in an inning, per game week, or at home is a significant measure in the prevention of painful elbow symptoms and UCL pathology.

Published guidelines for parents and coaches are standards to be adhered to with regard to pitch count totals for fast balls and changeups. Whether to use the skeletal or the clinical age to determine when to learn to throw the curve balls is a matter of controversy. One sage orthopedic team physician stated that optimally the best age for throwing the curve balls is when the athlete is old enough to shave. It behooves the sports medicine physician to vigorously encourage an educational program directed at parents, coaches, and school administrators that outlines the factors that must be ameliorated to reduce the incidences of premature medial elbow pathology.

Level IV

The orthopedic team physician, who has served as the primary orthopedic surgeon, director, and consultant to a Division I athletic department, maintains a specialty practice in a metropolitan setting, either in a multicentered hospital or in a building on the campus of the medical school. Because of clinical success, surgical prowess, and skill in treating professional athletes, recreational sports enthusiasts, and others with shoulder, elbow, and knee musculoskeletal pathology, the surgeon's renown in sports circles has escalated. Continued success is due to the orthopedic team physician's proficiency in using the arthroscope and the greatly improved, accurate diagnostic capabilities with radiological interpretation. Intra-operative local and general anesthesia, control of postoperative pain, early mobilization, and a proficient rehabilitation unit are salient features of a successful orthopedic sports medicine practice. This entire entity is now delineated as a center. Soon the sports medicine center becomes identified in that geographic area with the principal orthopedist. In time, another center comes up, and competition for fellows and for identification with a prominent athletic program ensues.

Although the sports orthopedist has been trained by prominent orthopedists and is perfectly capable of performing essentially all musculoskeletal operations, he or she soon realizes the need for other specialists in the group whose interests are primarily hand, neck-back, foot-ankle, and general trauma.

Along with the rapid growth and popularity of sports activity in all ages, there evolved the need to determine the etiology of many of these musculoskeletal injuries. Hence, biomechanical facilities came of age. Initially, characteristic motions of elite athletes were filmed—for example, pitching, passing, and hitting a golf ball. From this information, angles, vectors, and acceleration of joint motions were determined and used as basic information on which other athletes were judged for form variations that may need to be altered. The biomechanics laboratory plays a diagnostic role for the sports orthopedist as a marker to strive for in alteration of motion, if possible, or the level to attain after definitive surgery and rehabilitation.

In the United States, about the time orthopedic fellowships became operational, there was a spirited movement also to create general sports medical fellowships. These selected individuals were board-eligible from essentially all nonsurgical medical residency programs. Characteristically, each man or woman had a keen interest in sports, accepted the guidelines of conduct and regulations imposed by state and national organizations, and demonstrated practice of his or her basic specialty successfully.

Within the orthopedic sports medicine group, these generalists would continue to have a formal practice in their specialty in order to satisfy their board requirements while rotating in the clinic in association with orthopedic fellows who are under the supervision of the team orthopedists or the medical sports–trained counterpart. Orthopedic and general sports medicine fellows tend to complement each other socially and share each others' views, experiences, and knowledge.

In addition, while the orthopedic fellows are in the operating room, the medical sports fellows triage new patients, provide care to others who do not need to be seen orthopedically, follow those in rehabilitation, and make scheduled visits to assigned high schools or colleges. In most established orthopedic team physicians' offices, the preadmission physical examination is performed by outside internal medicine sources, so that the general sports medicine fellow usually is not primarily responsible for that duty.

Both orthopedic and general medicine fellows are given research projects to be completed, if possible, within the year. A formal presentation by each fellow is made to the entire staff and families, and monetary awards are given for excellence and merit. The completed research manuscripts must be designed to comply with the criteria outlined by the referred journals. Ancillary services provided by the orthopedic medical center for the fellows include a staffed library, available secretarial assistance, patients' history files, and available sports-oriented biomechanics. Each fellow is expected to report accurately and succinctly every patient contact, as well as the formal medical opinions expressed by the attending staff member.

Biweekly scientific seminars on assigned topics are delivered initially by fellows' clinical mentors and later by the fellows on specific subjects and on their research progress. Attendance is essential. Usually, monthly journal clubs are convened at a staff member's home or a comparable facility, where discussion of the assigned articles is led by the fellows' clinical mentors.

The fundamental aims of each fellow are to endeavor to increase general knowledge and to develop skills. Also, each must generate an awareness of sport injuries and their diagnoses, treatment, rehabilitation, and prevention. Learning and applying this information mutually results in confidence and accuracy of diagnosis.

Each sports medicine orthopedist or medical center develops a relationship with a school or university to cover that school's sports program. All fellows participate in preparticipation examinations. In addition, each fellow is assigned to a high school and a college team to visit weekly and attend football games. Because of the operating duties of the orthopedist fellows, much of this coverage falls on the general sports medicine fellows. Another practical learning session occurs in the special emergency room area for injury coverage on Friday nights after football games in the orthopedic center's locality. In season, players, cheerleaders, coaches, and officials are brought to a portion of the emergency room and initially examined by the team physician and the general sports medicine fellow, along with backup from the orthopedic fellow. Decisions are made, treatment is instituted, and rehabilitation is begun by the centers' assigned trainers, and office visits are scheduled.

The continued success of an orthopedic center potentially depends on referrals from schools that have established a sideline and midweek coverage relationship. Other noncovered schools and junior colleges in the surrounding area served by the orthopedic center may request preparticipation physical examinations. The general sports medicine fellows will use this experience profitably by suggesting care, treatment, and rehabilitation and arranging orthopedic consultations.

The orthopedic fellows, while in the operating room under expert tutelage, must avail themselves of the opportunities to improve their operative techniques, to visualize new surgical procedures, and to observe the proper postoperative care designed for that particular operation. Rounds of postsurgical patients are characterized by a blend of the previous experience of the fellows and that of the staff orthopedist. Absorption of this experience plus that gained on outpatient follow-up evaluation is essential. Initially, the fellow checks the chart, obtains the history, examines the surgical site, and then presents the information to the staff orthopedist. General sports medicine fellows who are rotating through the orthopedic service are often included in postsurgical, outpatient rounds. This exposure is priceless, fundamentally, but the interplay of both categories of fellows is bilaterally profitable at that time and also in the future when in practice.

Toward the end of this fellowship, the fellows prepare to make significant future plans. Some plans were begun back in residency and some after contacts when attending professional organizational meetings. A few are referred by staff personnel and pertain to specific situations. A very few fellows will sign a contract to go to a foreign country for a lucrative fee to help pay their education bills. It is noteworthy that most fellows going out into practice have not considered a short-term medical or orthopedic missionary trip. The vast majority of fellows already have engaged a lawyer to include certain aspects of insurance, coverage, promotions to partners, percentage of profits and overhead, and area of noncompetition. Family input into decisions is desired, and when this is lacking, it may lead to unhappiness and separation.

Level V

It is extremely rare for a fellow who has recently completed his or her fellowship to step into the position of head team physician of a professional team. Should the new partner be fortunate to come on board and learn that the senior orthopedic partner currently is firmly entrenched as team physician of a professional American football team, a wonderful opportunity ensues to learn what the senior partner has seen and experienced over the years! Equipment has improved, research has brought about rule changes, treatment is now scientifically based, and surgical procedures are more advanced. In recent years, the National Football League (NFL) has instituted a pre-affiliation screening of recently graduated college players for athletic ability, as well as for identifying orthopedic or medical problems. This evaluation process is called a "combine" because all the professional football teams' orthopedic team physicians are eligible to participate. Also, other team physician specialists' services are used when expert opinions are needed for unusual cardiac, pulmonary, psychological, hematological, neurological, and radiological situations.

By now, the professional team physician, the orthopedist, and the generalist have gained a broad base of experience outside their primary specialty. After a specific plan of action is determined for a specific entity, the player, the team, coaches, and agents must be informed and an agreement reached. The action must be recognized by code number for insurance purposes. The effectiveness of rehabilitation has to be determined to accurately predict return to play. History of the players' dependability, substance participation, and psychological makeup may determine long-range surgical success. Follow-up arrangements with trainers and physiotherapists to use published protocols are mandatory.

It would be wise for the team physicians who aspire to a professional association to visit the U.S. Olympic training center in Colorado Springs, Colorado. Essentially, every Olympic sports federation trains there, so that contacts can be established and training facilities and methods critiqued. Each federation, although somewhat political in nature, benefits by engaging an enthusiastic and knowledgeable team physician. The experiences are rewarding and mutually beneficial.

In addition to the examples of the NFL and Olympic teams, there is an abundance of professional and semiprofessional sports teams in the United States and Europe whose longevity depends on the competence of their team physicians in routine preparticipation evaluations, treatment of orthopedic and medical situations, and preventative care. Also, professional companies of performers, such as the circus or a theatrical group, or entertainment troops depend on orthopedic and sports medicine coverage to maintain a rigorous schedule. In these instances, the orthopedist is the primary physician with a sports medical backup. In others, the reverse may be noted. Cooperation is paramount to successful interplay.

Industry uses fellowship-trained sports physicians to evaluate workers' abilities to perform certain physical tasks as well as to ascertain the merit of worker's compensation cases. Many large manufacturers provide the doctor with an office and staff support within the plant to determine applicants' capabilities with regard to job requirements, introduce new safety features, treat injuries and illnesses, determine the percentage of disability, and promote good health habits among employees. Problems do occur with lawyers and union officials when employment termination is needed.

Sports physicians, both orthopedists and medical generalists, at times are openly solicited by pharmaceutical corporations. These recruited physicians are extremely valuable in evaluating clinical trials, especially those related to musculoskeletal effects. Writing a prospectus or a protocol and developing clinical results for publication often reflect fellowship training and personal inclinations. Being engulfed in medicine and clinical outcomes is exciting and an adjunct to clinical practice. To those scientifically inclined, the application of stem cells in the treatment of ligamentous and tendinous pathology would be intriguing.

There are qualified sports physicians employed by international steamship lines not only to examine and care for the crew, but also to hold sick call in order to determine the extent of illness or injury and ascertain the need for removal from ship. Paramedical personnel are provided, and the ports of call are very interesting.

In summer, coaches tend to schedule sports camps for high school and college students at their own university or at a convenient site that is easily accessible. The camps may vary depending on the sport, level of expertise, and position. A full complement of coaches, therapists, trainers, and emergency personnel are housed on campus or at a hotel for a 7- to 10-day period. The qualified sports medicine physician, orthopedist, or generalist signs up or volunteers for previous or future gratuities and enjoys the change of venue and a vacation.

Before entering into a professional relationship as a qualified sport physician to an entity, group, or physical situation, considerable investigation, contemplation, and consultation with an attorney who is knowledgeable in that particular environment are required for the subsequent contract to be mutually gratifying.

James A. Whiteside

See also Fieldside Assessment and Triage; History of Sports Medicine; Legal Aspects of Sports Medicine; Running a Sports Medicine Practice

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Temperature and Humidity, Effects on Exercise

Different environmental conditions, such as temperature and humidity, affect exercise tolerance and capacity in many ways. It is important for athletes to maintain their body temperature at or near 98.6 °F. Environmental conditions, in particular air temperature and humidity, determine the rate at which heat is lost or gained for the exercising athlete.

The body is able to regulate core temperature within a narrow range and must be able to manage heat transfer by convection, conduction, or evaporation. When the outside temperature is cooler than an athlete's body temperature, heat will be lost from the skin to the environment through conduction. The rate at which this heat is lost will be determined by the temperature difference between the environment and the athlete's body. Continual replacement of the warmer air near the body by cooler air from the environment causes loss of heat from the body by means of convection. Convective heat loss is determined by the speed at which air flows across the body. Evaporation is the most effective way in which the body loses heat. However, with high humidity, sweat loss by evaporation is reduced.

At rest, athletes regulate their body temperature around 98.6 °F. Muscles produce more heat during exercise than at rest. The thermoregulation system of the body must compensate for this increase in heat production, and inability to do so could lead to hyperthermia. External factors such as extreme temperatures and humidity also contribute to the development of both hyperthermia and hypothermia.

Hypothermia

When environmental conditions are particularly cold, there is a risk that the athlete will lose heat faster than he or she can produce it. Under these conditions, the body may be unable to maintain a safe temperature, leading to *hypothermia*. Swimmers are particularly at risk because cold water is an excellent conductor of heat, approximately 30 times more effective than air, and the body may be unable to produce heat as rapidly as it is lost by conduction to the surrounding water.

Hypothermia Prevention

There is a high rate of heat production during exercise, but once an athlete stops exercising, this rate falls sharply, and the risk of hypothermia rises significantly. Wearing proper clothing and gear is important in preventing hypothermia. Air is a poor conductor of heat but makes a good insulator. In contrast, water is a very poor insulator but a great conductor; therefore, a thin layer of air trapped next to the skin by specialized clothing creates a layer of insulation, thereby lessening the likelihood of developing hypothermia.

Hypothermia Diagnosis and Treatment

Hypothermia can be diagnosed when an athlete has been exercising in a cold environment, his or her core temperature is low, and he or she has fatigue, disorientation, muscle weakness, or loss of coordination. The treatment of hypothermia begins with removal of the athlete from the cold environment and applying dry clothing and external heating methods, such as convective heat, hot water bottles in the groin and axilla, or heated intravenous fluids.

Hyperthermia

Hyperthermia is described as an increase in body temperature above the normal resting upper limit. Elevated body temperatures occur with exercise because athletes produce heat when exercising, and this exceeds the capacity of the hot environment to absorb that heat. The humidity of the air determines the extent to which heat can be transferred from the body to the environment in the form of sweat. Sweat evaporates from the skin surface, involving a phase change from liquid to gas, which cools the surface of the skin. However, as the humidity of the air rises, the efficiency of heat loss by evaporation falls, and the body may be unable to balance heat production and heat loss.

Hyperthermia Diagnosis and Treatment

The most important aspect of diagnosing heat illness is to recognize the early signs, before the athlete has progressed to the later stages of the illness. Evaluate the athlete's core temperature, amount of sweating, and thirst. If heat illness is suspected, a thorough musculoskeletal and neurologic examination should be performed, noting any confusion, dizziness, or nausea, as well as noting core temperature, all of which could lead to early diagnosis, treatment, and prevention of the progression of heat illness.

Heat cramps can be treated on the field, and once cramping has ceased, return to play is allowed after ensuring proper hydration and electrolyte supplementation. With heat exhaustion and heat stroke, the primary goal should be to return the athlete's core temperature to normal. Cooling the athlete should be the first and most important action taken. Different facilities will have different methods available, including immersion in cool water, misting fans, and cooling vests.

Hyperthermia Prevention

There are many steps that can be taken to reduce the chances of heat illness. Avoid exercising in the middle of the day, when temperature and humidity are at their highest; ensure appropriate fluid and electrolyte replacement; be aware of the signs and symptoms of heat illness; and act according to the limitations of one's body. Have sufficient cooling methods and appropriate fluids on the sidelines of games to ensure that if athletes begin to struggle with heat illness, proper treatments are available. It is also important to note that once an athlete has suffered from heat exhaustion or heat stroke, he or she is at risk for recurrence. Heat illnesses are avoidable if the proper precautions are taken and if the signs and symptoms of the earlier stages are recognized and treated appropriately.

Blake R. Boggess and Cameron Howes

See also Cramping; Heat Illness

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Tendinitis, Tendinosis

Tendons are vital components of the musculoskeletal system as they serve to attach the contractile units of the body (muscles) to the levers (bones). They are thereby responsible for the transmission of the forces required to produce movement. The cross-sectional areas of tendons are small in relation to their attached muscles, and therefore, the stress (force per unit area) they are exposed to is substantial during activity. It is perhaps no surprise, therefore, that they are subject to inflammatory and degenerative pathology. Tendon injuries are reported to account for up to 30% of all running-related injuries and can result in considerable morbidity lasting several months despite appropriate management.

Tendon Structure

Macroscopically healthy tendons are white in color and are found in a variety of forms, from rounded cords to flattened ribbons, depending on their function and anatomical site. Normal adult tendon fibers are composed predominantly of large Type I collagen fibrils (65–80% of the dry mass) arranged in a ropelike configuration with smaller amounts of Type III collagen, proteoglycans, and elastic fibers (2%). The predominant cells found within the tendon structure are tenocytes and tenoblasts (immature tenocytes), which account for 90% to 95% of the cell population. These cells lie between the collagen fibers along the long axis of the tendon. The remaining cells include chondrocytes at the tendon insertion sites, the synovial cells of the tendon sheath, and vascular cells. The endotenon, a thin retinacular structure, invests each tendon fiber. The epitenon surrounds the tendon and contains the vascular, lymphatic, and nerve supply and is in turn surrounded superficially by the paratenon. Synovial tendon sheaths, consisting of an outer fibrotic sheath and an inner synovial sheath, may be found in areas subject to increased mechanical stress, where efficient lubrication is required. The inner sheath produces synovial fluid by a process of ultrafiltration. At the myotendinous junction, the weakest point of the musculotendinous unit, collagen fibrils of the tendon insert into deep recesses formed by the myocytes of the associated muscle. The osteotendinous junction is composed of four zones (dense tendon zone, fibrocartilage, mineralized fibrocartilage, and bone). The blood supply of tendons originates from intrinsic systems at the myotendinous and osseotendinous junctions and an extrinsic system through the paratenon or synovial sheath.

Contrary to traditional beliefs, tendons are metabolically active. Tenocytes have a low metabolic rate and a well-developed anaerobic energy generation capacity that allows them to resist load and maintain tension for prolonged periods. Animal studies suggest that the physical properties of tendons (tensile strength, stiffness, collagen content, and cross-sectional area) are all enhanced with physical activity. Type I collagen synthesis in particular depends on overall protein synthesis and on tensile loading and is thought to occur in a nonuniform way throughout the tendon structure.

Pathophysiology

The relationship between *tendinosis* (degeneration without inflammation) and *tendinitis* (inflammation) is unclear. The terms are often used interchangeably, leading to confusion. The best generic descriptive term for clinical conditions arising in and around tendons is *tendinopathy*. The low metabolic rate that makes the cells of the tendon suitably adapted for their role in load bearing also, however, results in delayed healing following injury. Tendinopathies tend to occur with greater frequency in the older athlete, and it is perhaps not surprising that with increasing age the metabolic pathways of tenocytes shift from aerobic to more anaerobic energy production. In addition, tendon vascularity is compromised at the junctional zones between the intrinsic and extrinsic systems or where there is localized torsion, friction, or compression. A good example of this is seen in the Achilles tendon, where there is a zone of hypovascularity 2 to 7 centimeters (cm) proximal to the tendon insertion, a common site of rupture. It is important to note that tendon blood flow also decreases with increasing age and mechanical loading.

Tendinopathy

Despite the relative frequency of tendon overuse injuries in sports medicine practice, the etiology of tendinosis and tendinitis remain unclear. The processes are multifactorial but on a local level are thought to be one of accumulated trauma as a result of repetitive mechanical loading. Tenocyte damage may occur as a result of localized hypoxia or as a result of free radicals produced during reperfusion after relaxation, which may be compounded by hyperthermia within the tendon produced by repeated or prolonged bouts of exercise. On a macroscopic level, there may be a combination of intrinsic factors such as malalignment, inflexibility, and muscle weakness or imbalance. Biomechanical faults, in particular hyperpronation of the foot, are reported to play a causative role in two thirds of Achilles tendon disorders in athletes. These may be exacerbated by age-related degeneration and diminished vascular supply. Tendons loaded beyond their physiological threshold respond by inflammation of their sheath (synovitis/tendinitis), degeneration of their body (tendinosis), or a combination of the two processes. Macroscopically, the diseased tendons look gray-brown and amorphous, and they may be thickened. Histological examination of tendons in symptomatic patients reveals disordered healing and noninflammatory degeneration. The fibers are thin and disorganized with scattered vascular in-growth. Inflammatory lesions and granulation tissue are infrequent in the chronic situation. Pain may result from a number of mechanical and biomechanical factors. Chemical irritants implicated in the production of pain include glutamate and Substance P.

Sites

Common sites of tendinopathies include the ankle (Achilles tendon/tibialis posterior), knee (patellar tendon), shoulder (supraspinatus tendon/bicipital tendon), and elbow ("tennis" elbow/"golfer's" elbow).

Diagnosis

The diagnosis of tendinopathy or tendinitis depends on the acquisition of a detailed history and a thorough examination. The patient generally complains of pain on loading the affected structure. There has often been a change in the frequency or intensity of activity prior to the onset of symptoms. Examination may reveal localized pain on deep palpation or thickening of the affected structure. Significant loss of function or the presence of a palpable defect should alert the examiner to the possibility of partial or complete tendon rupture. Magnetic resonance imaging (MRI) or ultrasound scanning with Doppler may be useful to identify changes within the tendon substance, including the increased blood flow associated with neovascularization.

Treatment

It is important at the outset to identify whether the problem is an acute episode with an inflammatory component or a chronic condition. Tendinopathies may require lengthy multimodal management, and patients often respond poorly to treatment. The mainstay of treatment is generally conservative. As in most conditions, the keystone of successful treatment lies in the accurate assessment of the factors contributing to the problem. These must then be systematically addressed during the treatment phase. Training patterns and the equipment used by the athlete should be assessed, preferably in conjunction with the coaching staff. Poor technique and "training errors" should be avoided, and where possible, biomechanical factors should be corrected. There is little convincing evidence for the use of nonsteroidal anti-inflammatory drugs (NSAIDs) in chronic tendinopathy, although they may be useful in the acute situation. It is important to recognize that in many sites, there is little evidence of a lasting benefit from the peritendinous injection of corticosteroids. If there is an inflammatory component such as a tenosynovitis or bursitis, these agents may be used to address any associated inflammation, and cautious use of locally applied ice may be helpful in providing pain relief. The degree of tendon loading that should be applied to promote healing is a matter of debate. Prolonged immobilization of tendons is detrimental, leading to tendon atrophy and reduced tensile strength. Controlled stretching is likely to increase collagen synthesis and improve the quality of the regenerate tendon.

Many physical therapies have been proposed for the treatment of tendinopathies, with little good-quality evidence for their efficacy. There is evidence from animal models of the usefulness of extracorporeal shock wave therapy (ESWT) in improving experimentally produced tendinopathy, but the results of clinical trials in humans are conflicting. Other treatments have included the use of pulsed magnetic fields, laser therapy, and radiofrequency coblation, again with variable results. There is good support for the use of an eccentric training program in short-term symptom relief in Achilles and patella tendinopathies. Other modalities used with conflicting evidence include dry needling, the image-guided injection of sclerosants, and the use of glyceryl trinitrate (GTN) patches. Surgical debridement of the macroscopically unhealthy tissue can be considered in cases resistant to other treatment modalities.

Future therapies may involve the use of cytokines and growth factors, gene transfer, or the implantation of mesenchymal stem cells to modify the healing environment.

Conclusion

The assessment and management of tendinopathies is one of the key skills required in the sports medicine practitioner. Further research and scientific evaluation of the available literature are required before evidence-based management protocols can be instituted.

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See also Achilles Tendinitis; Patellar Tendinitis; Peroneal Tendinitis; Tendinopathy

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Tendinopathy

Overuse or exercise-related tendon injuries are common in competitive and recreational athletes, as well as in manual laborers. *Tendinopathy*, the term used to describe an overuse tendon injury or disorder, usually presents as pain in the region of the involved tendon. Tendinopathy usually results from chronic repetitive overuse or subclinical injury rather than a single acute injury. Under the Bonar classification, tendinopathy includes tendinosis (degenerative change of the tendon), tendinitis (inflammation of the tendon) with tendinosis, paratenonitis (inflammation of the tendon outer covering), and tendinosis with paratenonitis (see Table 1). Some examples of common tendinopathies are listed in Table 2.

While there is some overlap in the symptoms and physical findings of patients with different causes of tendon pain, the patient's symptom history provides important clues to help in correctly diagnosing and treating the underlying tendon injury. In addition to guiding appropriate treatment, proper diagnosis also provides the ability to properly educate patients about the expected course of their tendon problem. One important clinical distinction in tendinopathy is between acute, inflammatory conditions (tendinitis, paratenonitis), and chronic, degenerative conditions (tendinosis). While inflammatory tendon conditions are usually self-limited and respond well to anti-inflammatory treatments, degenerative tendon changes, since they are usually chronic, typically require a more robust, long-term treatment plan focused on reversing the degenerative process. Furthermore, because inflammatory and degenerative conditions often coexist, both must be considered in developing an appropriate short- and long-term treatment plan.

Anatomy

Tendons are predominately Type I collagen, which consists of tropocollagen chains grouped in a triple helix arrangement. These triple helices are very closely grouped longitudinally in the tendon, with each level of organization being surrounded by an outer covering. The entire tendon is also surrounded by an external covering called the *paratenon*. In areas where tendons bend at acute angles (e.g., the flexor tendons of the fingers) over bone, the paratenon is usually thicker and lined with synovium, which not only provides mechanical resistance to shearing forces but also produces synovial fluid, lubricating the tendon to decrease frictional injury. This is also commonly referred to as the tendon sheath. It is in these areas that the inflammation can commonly occur, causing synovial fluid production and associated swelling (e.g., intersection syndrome). In the remaining tendon areas, the paratenon is thinner and not lined with synovium.

Causes

As mentioned previously, tendinopathy usually results from chronic overuse microtrauma to a tendon. The precise pathogenesis of tendinopathy is still unknown, but general causative mechanisms

Table 1 Classification of Tendinopathies

Tendon Condition	*Formerly Used Terms*	*Macroscopic Appearance/Pathology*
Normal tendon		White, glistening, firm
Tendinosis	Tendinitis	Dull, slightly brown, soft; intratendinous degeneration
Tendinitis with tendinosis	Tendinitis	Intratendinous inflammation (repair response) superimposed on tendinosis
Paratenonitis	Tenosynovitis, tenovaginitis, peritendinitis	Inflammation of the outer tendon layer
Paratenonitis with tendinosis	Tendinitis	Combined degenerative changes of paratenonitis with degenerative changes of tendinosis

Table 2 Common Tendinopathies

Tendon	*Paratenon Synovial Lining?*	*Common Tendinopathy*
Rotator cuff tendons		
Supraspinatus	No	Supraspinatus tendinosis (due to subacromial impingement)
Infraspinatus	No	Rotator cuff tendinosis
Teres minor	No	Rotator cuff tendinosis
Subscapularis	No	Rotator cuff tendinosis
Biceps brachii	Yes (long head in intertubercular groove)	Biceps paratenonitis (long head), biceps tendinosis (long head) ± paratenonitis
Common wrist extensor	No	Medial epicondylosis
Common wrist flexor	No	Lateral epicondylosis
Flexor digitorum tendons (superficial and deep)	Yes (over carpal bones)	Flexor digitorum paratenonitis, Flexor digitorum tendinosis ± paratenonitis
Abductor pollicis longus (APL), Extensor pollicis brevis (EPB), Extensor carpi radialis longus (ECRL), Extensor carpi radialis brevis (ECRB)	Yes (over carpal bones)	APL/EPB paratenonitis (de Quervain), APL/EPB/ECRL/ECRB paratenonitis (intersection syndrome)
Patella	No	Patellar tendinosis
Achilles	No	Achilles tendinosis
Posterior tibialis	Yes	Posterior tibialis paratenonitis, Posterior tibialis tendinosis ± paratenonitis

are becoming more clearly understood. Other than paratenonitis, all other categories of tendinopathy have a component of tendinosis or degenerative tendon changes. It is now understood that these changes can occur as early as 3 weeks after the start of the overuse injury.

While general aging and tendon underuse can contribute to degenerative tendon changes, most tendinopathy is caused by any combination of excessive repetition, anatomic abnormality (e.g., limb length discrepancy), malalignment (e.g., hyperpronation), muscle imbalance or weakness, improper technique, improper equipment, and incomplete recovery after overuse. These etiologies hold true for competitive and recreational athletes as well as for recreational and vocational laborers.

Clinical Evaluation

History

While a patient complaint of pain over a tendon clearly causes one to consider tendinopathy, the clinical history is very important in helping distinguish among the types of tendinopathy. A patient with only paratenonitis will usually complain of a recent increase in his or her activity level or intensity, such as a soccer athlete with ankle hyperpronation who complains of posterior tibialis pain and swelling 1 week after starting preseason conditioning. Of note, pain from paratenonitis will usually be constant and proportional to activity level.

A patient with tendinosis will usually have a prior history of overuse, such as playing competitive tennis in a patient with supraspinatus tendinosis or playing competitive basketball in a patient with patellar tendinosis. Furthermore, tendon pain from tendinosis will typically start during the warm-up phase and, in less advanced disease, decrease during activity and increase during the warm-down and recovery phases. Additionally, pain from tendinosis is usually sharp and more intense early and becomes duller and more achy later in the disease process.

In the evaluation of tendon pain, it is also important to rule out other causes of the patient's pain. Most patients with tendinopathy should not have associated paresthesia, weakness, radiation of pain, blunt trauma, fever, and overlying skin changes. Furthermore, pain from tendinopathy should not persist with relative rest and should not cause night symptoms.

Physical Examination

Physical examination is useful to distinguish inflammatory from noninflammatory tendinopathy. Patients with tendinopathy will have pain with palpation of a tendon under strain using manual muscle testing. As with most inflammatory conditions, patients with paratenonitis or tendinitis complicating tendinosis will often have associated swelling and increased temperature over the affected area of the tendon. Additionally, patients with these conditions can have crepitus with passive joint range of motion, moving the tendon back and forth.

Imaging

Clinical assessment is usually sufficient for the diagnosis and classification of tendinopathy. However, magnetic resonance imaging (MRI) and ultrasound can be helpful adjuncts in assessing tendinopathy. Areas of tendinosis will be most visible as hypoechoic regions on an ultrasound scan and increased signal on T2 and STIR (short T1 inversion recovery) sequences on an MRI scan. However, imaging can also complicate the clinical picture because a high percentage of asymptomatic patients can have evidence of tendinosis on imaging, especially of the rotator cuff in older patients.

Treatment

The mainstay of tendinopathy treatment has been conservative therapy relying on relative rest, ice, and nonsteroidal anti-inflammatory medications (NSAIDs). While modalities to decrease inflammation, such as steroid anti-inflammatory medications (either local or systemic), may be of benefit in proven cases of paratenonitis or tendinitis complicating tendinosis, these medications do not treat the underlying pathology of tendinosis when present. Furthermore, because NSAIDs mostly have analgesic properties, if not coupled with reversal of the causative factors and relative rest, further injury may ensue.

The most widely accepted treatment modality for reforming degenerative tendon has been eccentric muscle strengthening of the affected muscle-tendon unit. There has been some suggestion that eccentric strengthening following soft tissue mobilization has further benefit, but this has not been borne out in the literature. Some other treatment modalities, such as topical nitric oxide and shock wave therapy, have been used but still remain experimental.

In rare cases of tendinosis that do not respond to a prolonged course of conservative treatment options, surgical treatment to remove a section of degenerative tendon may be indicated. Athletes must understand that surgery will not hasten their return to sports and often will guarantee a 6- to 12-month hiatus from full competition.

The most important part of any treatment plan for tendinopathy includes correction of the underlying cause. If the patient has a muscular insufficiency or imbalance, proper identification and physical therapy are essential. If errors in technique or training schedules are identified and corrected as part of the treatment, the patient will often see long-term benefit.

Conclusion

Tendinopathy is a common condition affecting athletes, resulting from overuse injury to the tendon.

Inflammatory conditions of the tendon do occur but predominately involve inflammation of the outer covering of the tendon, or paratenon. More commonly, patients have underlying tendon degeneration, or tendinosis. These patients require a robust treatment plan, including eccentric strengthening exercises and correction of modifiable risk factors, such as muscle imbalances and training errors.

Jeffrey D. Smithers

See also Tendinitis, Tendinosis

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Tennis and Racquet Sports, Injuries in

Injuries are common in players of racquet sports. A retrospective analysis of sports injuries in 2000 showed squash injuries to be more frequent than tennis and badminton injuries, with more men injured overall than women and with persons over age 25 more vulnerable to injuries. The higher proportion of squash injuries were attributed to greater physical stress and more contact. Acute traumatic injuries were seen especially in squash players, most often affecting the knee, lumbar region, and ankle. The most common tennis injuries were lateral epicondylitis, patellofemoral pain, and lumbar disk prolapse. The badminton injury pattern overlapped the others. Lower limb injuries predominated in all racquet sports. Detailed assessment of 106 cases showed many to be new, infrequent, social players. Poor warm-up was a common factor in both new and established players.

Typically, injuries in racquet sports are overuse injuries. These result from repetitive stresses and minor traumatic events, such as the effect on the shoulder of serving thousands of times or the influence on the knee of playing hundreds of points with pivots, twist, and aggressive stops and starts.

Tennis injuries may be categorized as either acute or chronic. *Acute injury* describes a new injury or complaint from the time it occurs and for the short time following the start of injury (e.g., ankle sprain). A *chronic injury* typically recurs or repeats itself due to continued tennis play or lack of proper rehabilitation (e.g., tennis elbow).

Among elite junior tennis players, injuries in descending order of frequency were as follows: back, 24%; shoulder, 21%; foot, 19%; knee, 15%; elbow, 12%; and ankle, 12%.

Head Injury

Although head injuries are uncommon in tennis, they sometimes occur, particularly in doubles play, where the bodies or racquets of two partners may come into contact.

Bruises and Cuts

Bruises are usually caused by being hit by the ball on a smash shot. It's more common in doubles play because the player at the net has less time to react. Being hit by the partner's racquet may also cause a bruise.

Bruises can usually be treated by icing them to reduce swelling and control pain. If the skin is broken, it is cleaned with soap and water, and an antiseptic spray or cream may be applied. Nonsteroidal anti-inflammatory drugs (NSAIDs) may provide pain relief. If a blow causes loss of concussion or memory, or disorientation, the player should be seen promptly by a physician.

Broken Nose

A blow to the nose by a racquet or ball can fracture the nasal bones or injure the cartilage of the septum—the structure that separates the two nostrils.

Any nose suspected to be broken should be iced down to limit swelling and bruising. The athlete should be seen by a physician, and radiographs should be taken. Once fixed, the nose is usually protected with a splint until it heals completely, which can take 4 to 6 weeks.

Eye Injuries

Most eye injuries in racquet sports are caused by being struck in the eye with the ball or, rarely, a blow from a partner's racquet. Eye injuries may cause bleeding into the orbit and surrounding tissues, scratch the cornea, cause bleeding inside the eye, or even cause a detached retina. Any injury to the eye should be examined promptly by an ophthalmologist.

Blowout Fracture

A blow to the eye or cheek from the racquet can fracture the orbital bones surrounding the eyeball. As with any fracture, an athlete who suffers a suspected blowout fracture must see a physician for treatment, which may include surgery.

Neck Injury

Along with the head, the neck area is affected in many racquet sports injuries. The neck is tremendously mobile to allow the head to swivel, so the range of motion between the vertebrae in the neck is greater than in the lower spine.

Pinched Nerve

An injury that initially may seem like a sprain but is actually more complex is a pinched nerve; this happens when a cervical disk ruptures or degenerates.

Tennis players, who may make fairly violent neck motions, are prone to pinched nerves. The problem usually responds to some form of cervical traction (neck brace) for 2 to 6 weeks, with accompanying physical therapy to reduce muscle spasm. However, if severe symptoms persist, particularly in the arm and the hand, surgery may be required to repair damage to the offending intervertebral disk.

Neck Muscle Injuries

Wryneck, or *spastic torticollis,* is due to a pulled muscle, or muscle spasm. The athlete who looks up and serves or hits an overhead smash may feel pain on one side of the neck, and the neck may be pulled over slightly to that side.

The proper treatment is to apply ice for 20 minutes at a time and gently stretch the neck. If the pain is severe, the athlete may need medication, such as a muscle relaxant or anti-inflammatory agent, and physical therapy.

Perhaps the best way to prevent neck injury is to strengthen the neck muscles. Every tennis player should work on improving neck strength. Basic exercises include applying resistance against oneself or by working with a partner.

Shoulder Injury

The shoulder is one of the most commonly injured joints among tennis players, particularly among junior elite players.

Rotator Cuff Injury

The *rotator cuff* is a group of muscles that work together to provide the shoulder joint with dynamic stability, helping to control the joint during rotation. The rotator cuff muscles include the supraspinatus, infraspinatus, teres minor, and subscapularis.

Due to the function of these muscles, sports that involve a lot of shoulder rotation—for example, tennis—often put the rotator cuff muscles under considerable stress. Rotator cuff injuries may range from an impingement to a complete tear. The impingement causes the nerves under the shoulder to fire and shoot pain down through the tendons of the shoulder into their connecting muscles. Tennis players feel the pain particularly in the long head of the biceps. Tennis players with this injury may be able to hit ground strokes effortlessly, but when they try to hit an overhead or serve, they experience shoulder pain.

Treatment for shoulder impingement may include a series of lifting and stretching exercises to strengthen the rotator cuff muscles and increase range of motion.

Shoulder Muscle Strain

A muscle strain can happen to almost any muscle in the body; the shoulder is particularly subject to such strains, or "pulls," which occur when a sudden, severe force is applied to the muscle and the fibers are stretched beyond their capacity. If only some of the fibers tear, it is called a muscle strain. If most of the fibers tear, it is called a muscle tear.

Common treatment for a muscle strain is a rest period, about 3 to 7 days, followed by stretching and then strengthening exercises.

Tennis Elbow

Lateral epicondylitis, or *tennis elbow*, is probably the most common of all upper extremity injuries in racquet sports. This term refers to the overuse injury resulting from repetitive trauma to the tendons that control wrist and forearm movement. Tennis elbow usually results from improper technique during backhands.

The single biggest factor in preventing tennis elbow is using a proper biomechanical tennis stroke technique. Rubber tubing exercises are used effectively to strengthen these muscles.

Treating tennis elbow requires an exercise program to increase the strength and flexibility of the forearm muscles and tendon.

Players with a history of tennis elbow or the athlete who feels elbow pain after play should wait at least half an hour after a match and then ice the elbow down, keeping the elbow cool for up to 30 to 40 minutes.

Grip size of the tennis racquet is important. The correct grip size is the distance from the proximal transverse palmar crease to the tip of the ring finger. An appropriate brace or splint for the forearm, applied distally to the elbow, is believed to dampen some of the shock that contributes to epicondylitis. Adequate warm-up, muscle stretching, and cooldown are always advisable. A physiological heat retainer may also be very useful and should be worn as often as possible.

Formerly, the standard treatment for tennis elbow was local cortisone injection. This form of therapy is no longer in wide use, especially as long-term treatment, because of reports of cortisone injections causing irreparable damage to the tendon.

Another type of tennis elbow causes pain on the inner side of the elbow (the medial epicondyle). This pain involves inflammation of the muscles and tendon that the palm faces down. Prevention and treatment measures are the same as for the first type of tennis elbow.

Torn Biceps

A sudden, severe movement of the arm can tear the biceps muscle. One head of the biceps can be literally torn in half. This is usually seen in an older tennis player who hits a hard forehand smash.

Treatment involves allowing the torn muscle to rest for 2 or 3 weeks while it heals. This is followed by a training program to strengthen the other head of the biceps so that it can take over the full function of the muscle. Arm curls are the best exercise to strengthen the biceps muscle.

Wrist Injuries

Racquetball and squash especially require a snapping motion of the wrist. Thus, the tendons and ligaments of the wrist are frequently injured.

Sprained Wrist

The most common injury to the wrist is a sprain. Strength and flexibility exercise of the muscles that cross the wrist helps protect the wrist and the ligaments that keep the wrist together.

Broken Wrist

A wrist usually fractures from a fall. Any severe wrist pain following a fall or a blow to wrist should be seen by a physician and X-rayed because of the possibility of fracture.

If the bone does not reknit, it probably will need to be fixed surgically.

Racquet Wrist

Tennis players may develop pain at the base of the hand, below the pinky finger. This usually occurs because the racquet butt is too large for the player's hand.

If the pain is severe, the athlete should see a physician. The little hook of bone at this location might be broken. If it is, then it will need to be treated as a fracture.

Tendinopathy

Overuse of the wrist in sports causes irritation of the finger tendons attached to these forearm muscles. This results in swelling, pain, and limited function in one or more of the fingers.

Treatment involves resting and icing the tendon in the wrist, followed by taking anti-inflammatory agents and immobilizing the thumb and wrist to reduce the inflammation. Appropriate strengthening exercises (e.g., ball squeezing) may be prescribed.

Carpal Tunnel Syndrome

Carpal tunnel syndrome is a painful disorder of the wrist and hand. The carpal tunnel is a narrow structure formed by the bones and other tissues of the wrist. This tunnel protects the median nerve, which gives feeling in the thumb, index, middle, and ring fingers. When surrounding tissues, such as ligaments and tendons, become swollen or inflamed, they press against the median nerve, causing pain or numbness. Anyone who tightly grips something while exercising, such as a tennis racquet, may suffer carpal tunnel syndrome.

The treatment is to rest the affected wrist and apply ice. In some cases, surgery is needed for relief of symptoms. Postoperatively, physical therapy with wrist and finger exercises is important to ensure good recovery and return to full function.

Arm Injuries

How equipment is used can affect the athlete's arm. String tension of the racquet is one important factor. Decreasing the racquet's string tension by a few (2–4) pounds (lb; 1 lb = 0.45 kilograms) is recommended for players who are experiencing shoulder, elbow, or wrist pain.

Research suggests that vibration dampeners have no affect on the arm itself; these dampeners do affect high-frequency vibration, such as that coming off the strings.

Knee Injuries

Knee injuries may occur in any racquet sport, but they are of particular concern in racquetball and squash, in which nearly every type of knee injury can occur.

Patellar pain syndrome may be the most frequently encountered condition in persons playing racquetball or squash. The syndrome usually has an insidious onset and is characterized by dull, aching, poorly localized pain that occasionally radiates to the sides and back of the knee. Initially, patellar pain syndrome occurs after activity; however, it can worsen to the extent that the knee is painful throughout the day. Swelling is rare.

Tennis obviously places a great deal of stress on the knee joint from bending, quick starts and stops, and explosive acceleration. Because tennis is a noncontact sport, the bone-crushing knee injuries we equate with football or skiing are not prevalent. With repeated stress to the legs, such as tennis play, and without sufficient strength and endurance of the thigh muscles, the kneecap can become irritated. This repeated irritation can wear down the back side of the kneecap and produce significant pain.

Preventing knee injuries in tennis focuses on two strategies: Strength and flexibility exercises, with proper biomechanics, form the platform for an injury prevention program.

Ankle and Foot Injuries

Acute ankle sprains are another of the most frequent injuries in racquetball and squash players. Most sprains are first degree and are treated in the usual fashion. Ice and elevation, combined with graded exercises, are recommended. Some trainers recommend extra support for the first 6 weeks after play is resumed.

Achilles tendon problems are also frequently encountered. Chronic Achilles tendinitis is characterized by gradually increasing pain that is aggravated by activity and relieved by rest. Rest is most important in the treatment of acute injury. Once pain subsides, gradual stretching of the tendon, along with calf strengthening, should be done.

Less common, and most dreaded, is rupture of the Achilles tendon. Usually, the player is trying to push back from a drop shot at the front of the court and hears a sudden snap, followed by immediate pain. In the Thompson "squeeze" test, the patient lies prone, and the examiner squeezes the calf muscle. An intact Achilles tendon will cause the foot to plantarflex, representing a negative test. The test is positive if this response is absent, due to a ruptured tendon. A tender, palpable swelling may be detected. Palpable or visible defects can also be found, although they may be obscured by bleeding. The patient walks flatfooted with a limp, not pushing off the toes. Treatment may be operative or nonoperative, and the decision is best left to an orthopedic surgeon.

The most common foot problems are related to blisters and calluses. Traditional treatment of blisters includes releasing the fluid, thereby allowing the underlying skin to harden. Some physicians prefer not to drain blisters, so as to avoid creating a portal for possible infection. If the patient wishes to continue playing while the blister heals, a small, doughnut-shaped dressing can alleviate pressure to allow healing. To prevent underlying blister formation, calluses should be smoothed with an emery board or pumice stone.

Plantar fasciitis is the most commonly seen orthopedic condition of the foot in racquet sports enthusiasts. It is characterized by pain at the medial tubercle of the os calcis, where the plantar fascia attaches. The pain may also radiate distally toward the toes or, more commonly, proximally. Most patients complain of pain that begins as they get out of bed, subsides after walking, and recurs later in the day or during a game. Shortening the amount of time spent playing racquet sports or ceasing play altogether is most helpful. This decrease in activity should be followed by the use of orthotics, heel cups, or corrective athletic shoes with good midfoot support.

Asuman Sahan

See also Achilles Tendinitis; Rotator Cuff Tears, Partial; Rotator Cuff Tendinopathy

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Tennis Elbow

Tennis elbow, or *lateral epicondylitis*, is characterized by pain at the lateral (outer) aspect of the elbow. The patient may also complain of tenderness on palpation of the area of concern, usually the dominant arm. This entity was first described in a scientific article in 1873, and since that time, the mechanism of injury, pathophysiology, and treatment of this condition have been much debated.

The disorder is due to overuse of the extensor carpi radialis brevis (ECRB) muscle, which originates at the lateral epicondylar region of the distal humerus. Tennis elbow can also be classified as *tendinitis,* indicating inflammation of the tendon, or *tendinosis,* indicating tissue damage to the tendon.

The most common cause of lateral epicondylitis is, as the common name suggests, tennis. It is estimated that tennis elbow occurs in 50% of tennis players. However, this condition is caused not only by tennis but also by any activity associated with repetitive extension (bending back) of the wrist. The activity initiates contraction of the muscles that cause the hand to extend (bend back). There is a significant increased risk of overuse injury if playing for more than 2 hours/week and more than two to four times per week. In players older than 40 years, the risk increases two- to threefold. Significant risk factors have been identified and include improper technique and the size and weight of the racquet.

Anatomy and Mechanism of Injury

To understand the mechanism of injury of this condition, knowledge of some basic anatomy of the elbow is helpful. The elbow is a hinge joint—a junction between two bones primarily connected to each other by ligaments and tendons from the muscles near the humerus. The humerus is a long bone originating from the shoulder and extending to the elbow. It has two bumps called *epicondyles*—one on the medial (closest to the body) side and one on the lateral (farthest from the body) side. The radius and ulna are the bones in the forearm. The tendon (connecting tissue) at the medial epicondyle attaches to a muscle that causes the forearm and wrist to bend forward. Similarly, there is a tendon that attaches to the extensor muscle (ECRB) at the lateral aspect of the elbow, which when contracted, causes the forearm and wrist to bend backward (extend). At this junction at the elbow, inflammation at the area of bone attachment (enthesopathy) can occur with repeated stress, which in turn, causes a biochemical change in the tendon at the lateral epicondyle area. Classically, this is caused by overexertion of the extensor muscle while performing a backhand stroke in a game of tennis or other activity causing repetitive forearm muscle contractions (see Figure 1).

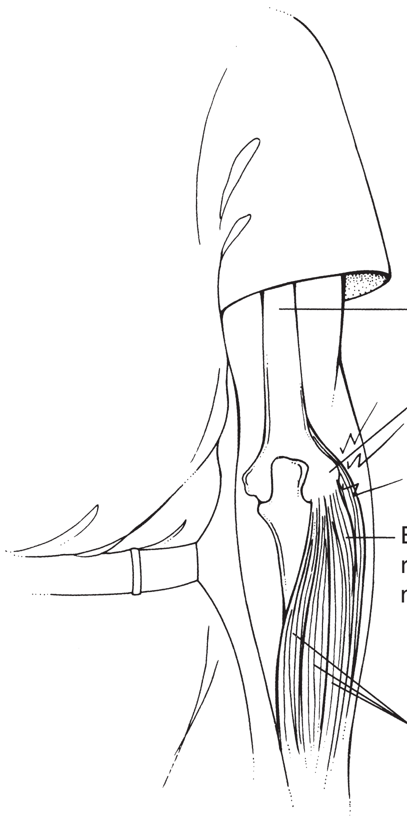

Figure 1 Tennis Elbow

Notes: Among the most common of overuse injuries, tennis elbow is caused by repetitive stress to the forearm muscles. This stress transmits to where the extensor muscle inserts into the lateral epicondyle of the humerus.

The pathophysiology of the condition involves inflammatory processes of the radial humeral bursa (fluid-filled sac) and nearby ligaments. This is caused by microscopic tearing with formation of scar tissue at the area of origin of the ECRB muscle tendon, so these small tears and subsequent repair in response may lead to larger tearing and eventual structural failure. Nirschl categorized this into four progressive stages:

Stage 1: Reversible inflammatory changes

Stage 2: Nonreversible pathologic changes

Stage 3: Rupture of ECRB muscle tendon origin

Stage 4: Tissue fibrosis or calcification noted as a secondary change

The patient may have one or more of the following complaints:

- A steadily increasing pain on the lateral part of the elbow.
- Pain that worsens with recreational activities such as playing tennis or gardening or with occupational activities such as painting walls.
- Pain that worsens when strongly squeezing the hand, shaking hands, or turning doorknobs.
- Pain that worsens with moving the wrist against resistance in any direction.
- Pain with handling a knife and fork and opening jars and, at times, even when driving or placing the hands and wrists in an extended position.
- Pain that may begin to occur at night and at rest without any activity.

The physical exam should include the following:

- Inspection of the area for any signs of trauma, swelling, erythema (redness), and deformity, as well as evaluation for asymmetry of the affected side versus the unaffected side.
- Evaluation of range of motion by the patient (actively) and by the examiner (passively).

- Palpation of the affected area to localize the area of tenderness as well as any nodules (bumps). It is worth noting that in some cases the etiology of pain at this location may be related to another condition called bursitis, which is inflammation of the bursa (a fluid-filled sac), which acts like a cushion; this may get irritated as well as infected. Typically, this area will be red, swollen, tender to the touch, and warm. Management could include rest, anti-inflammatory medication, and antibiotics in case of bacterial infection. So proper evaluation is crucial.
- Special stress testing to test whether resistance of the motion initiated by the patient (bending back the wrist while resisted by the examiner) will reproduce or worsen the pain. This would indicate a positive screening test.

Imaging Studies and Electrical Stimulation Study

Radiographs can help in ruling out other disorders or concomitant intraarticular pathology—for example, osteochondral loose body, posterior osteophytes (bone spurs). Calcification in the degenerative tissue of the ECRB muscle origin can be seen in chronic cases.

If indicated, magnetic resonance imaging (MRI) can confirm the presence of degenerative tissue in the ECRB muscle origin and can help diagnose concomitant pathology; however, it is very rarely needed and is usually expensive.

If clinical examination indicates a possible neural involvement with the patient's symptoms, electromyography (EMG) can be used to exclude posterior interosseous nerve compression syndrome (compression of the nerve).

Diagnostic procedures other than the common standards test may include a localized anesthetic injection into the area of concern, which is both diagnostic and therapeutic if the patient experiences relief from his or her symptoms.

Management

Nonsurgical

Generally, early, nonsurgical intervention is sufficient for the management of tennis elbow. Surgical intervention is not readily done due to the potential for scarring and for complications developing during and after the surgery.

Phase 1: Decrease or stop activity for 2 weeks

- Apply ice on the painful area 10 minutes on, 2 hours off for a day.
- Take ibuprofen for 10 days as prescribed, along with topical pain medication.
- Wear a wrist counterforce brace or splint to keep the wrist straight and avoid extension of the wrist or near the elbow to decrease tension on the muscle.

Usually, the symptoms will improve in 2 to 4 weeks.

Phase 2: If the above interventions do not help decrease the symptoms partially or completely, then consider an injection of corticosteroid in combination with a fast-acting anesthetic. These injections are fairly effective; however, chronic and repetitive use (more than two to three times) in the specific area of injection may cause further degeneration of the tendon. Also, a corticosteroid injection may cause wasting of the fatty tissue just below the skin.

Phase 3: Surgery is used only as a last method of intervention, after all other methods of treatment have been tried without improvement for 6 months. Even then, patients should consider surgery only when the symptoms have worsened to the extent of impairing function and activities of daily living due to pain. The surgery can be performed either arthroscopically (using a fiberoptic scope) through a tiny opening in the elbow (which creates a small scar) or by traditional open incision method (which causes a slightly bigger scar). Neither method has an advantage in postsurgical rehabilitation or functionality over the other method; the choice of technique is based on the surgeon's preference and experience, as well as the patient's preference.

Postsurgical Rehabilitation

1. After surgery, the elbow will be placed in a brace and the patient will be sent home with some pain medications as well as a directive to keep the area of incision clean and dry.
2. The patient will return in 5 to 7 days for a follow-up visit, and if the wound is healing well, the sutures will be removed.

3. If everything goes well, the brace will also be removed. Light stretching will be started, along with mild and gentle restoration of range of motion.
4. After 2 months, strength rehabilitation is started lightly and gradually as tolerated.

At this time, the physician will permit resumption of normal and recreational activities as appropriate. About 80% of the time, surgical intervention will be successful; however, one should allocate 4 to 6 months for complete recovery.

Prevention is the key to avoiding progression to surgical treatment. Patients should not delay seeking medical consultation at the earliest onset of symptoms.

George Kolo

See also Elbow and Forearm Injuries; Sports Injuries, Overuse; Tennis and Racquet Sports, Injuries in

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Testicle, Undescended or Solitary

Diseases, congenital anomalies, cryptorchidism (the undescended testicle), trauma, and their treatment may leave a child with a solitary testicle. When these youths come to the office for clearance to play sports, especially contact-collision sports, their reproductive future is at stake. A decision must be made as to whether it is safe to allow them to play.

Evidence from multiple pediatric trauma registries and thousands of contact-collision sports exposures suggests that the risk to the solitary testicle is not significant. In the injury surveillance data gathered from team sports at high school and collegiate levels, there is no evidence showing that these males have a significantly increased risk. For example, the National Pediatric Trauma Registry studied injuries in classic contact-collision sports over a 10-year period. There was only one testicle injury. The testicles are freely mobile, which may protect them from crush injury and disruption. Given a slight hypothetical risk, the recommendation by numerous sports medicine societies, including Medical the American Academy of Pediatrics, is unrestricted full clearance to play in contact-collision sports using a cup, after discussion of the potential risks. In other countries, the clearance-to-play recommendation is not so clear. In Australian rugby, there were 14 injuries, 11 with complete testicle loss, in a group of 15- to 19-year-olds from 1980 to 1993. Finally, the athletes should be given the option of sperm banking, if that is appropriate for their situation.

Cryptorchidism has a prevalence of 2% to 4% in babies weighing more than 2,500 grams (g), which decreases to 0.7% to 1% by the time these children reach 1 year of age. The obvious risk of an undescended testicle is testicular cancer. This risk increases concomitantly with the duration of the cryptorchidism. Most males have already had orchiopexy by the time they reach middle school and have no increased risk of cancer. Unfortunately, undescended testicles are still found in teenagers and in as many as 1% of U.S. military recruits.

The preparticipation exam offers an opportune occasion to find undescended testicles before they pose an increased risk of cancer. Several states now require early periodic screening, diagnosis, and treatment physicals (i.e., well-child exams) at the same time as sports physicals for seventh and ninth graders. This is an excellent time when the physician can perform a comprehensive physical and directly reduce the risk of testicular cancer in individuals found to have cryptorchidism. If an undescended testicle is discovered, the physician should make an immediate referral to a urologist to remove the testicle and repair the inguinal hernia that usually coexists with it.

James Dunlap

See also Abdominal Injuries; Presports Physical Examination

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Therapeutic Exercise

Therapeutic exercise is the systematic application of movement to joints and muscles to assist in the recovery from illness or injury. Therapeutic exercises are usually of a lower intensity and shorter duration than exercises used for conditioning healthy athletes. An individualized therapeutic exercise program is established after a rehabilitation professional obtains a full history and performs a comprehensive evaluation of the athlete.

The overall goal of a therapeutic exercise program in sports medicine is to return the athletes to their baseline level of function in their sport. This process can take a few days to several months depending on the injury. As the athlete advances through the stages of recovery, the exercise program is revised to progressively challenge the neuromusculoskeletal system in a safe manner. The components of a therapeutic exercise program will be discussed in this entry.

Exercise Parameters

Exercise parameters are an integral part of the therapeutic program and should be determined for each exercise. Parameters include frequency, intensity, duration, repetitions, sets, and rest. *Frequency* refers to how often each aspect of the exercise program is performed. *Intensity* refers to the difficulty of the activity. The unit of measurement varies for different types of exercise. *Duration* refers to the length of time an exercise is performed in a given session. *Repetitions* are the number of times an exercise is performed in one set. A *set* is a fixed number of repetitions of an exercise performed without rest. *Rest* refers to the length of time of resting between sets.

Types of Muscle Contraction

Muscles can contract *isometrically* or *isotonically*. Isometric contractions generate muscle force, but no joint movement occurs, such as holding a squat for 10 seconds. Isotonic contractions occur when the muscle contracts and joint movement occurs. There are two types of isotonic contractions. Concentric contractions occur when the muscle fibers shorten as the muscle contracts, such as the lifting phase of a biceps curl. Eccentric contractions occur when the muscle fibers lengthen, such as the lowering phase of a biceps curl.

Position of the Exercise

The body or segment can be positioned in relation to gravity to change the demands of the exercise. Antigravity exercises are performed in an upward direction, or against gravity. Gravity-eliminated exercises are performed in a horizontal plane, which is perpendicular to the force of gravity. Gravity-assisted exercises are performed in a downward direction, or in the same direction as the force of gravity. Exercises can be performed with the affected part in a weight-bearing or closed-chain position or in a non–weight bearing or open-chain position. Push-ups are an example of a closed-chain exercise. Biceps curls are an open-chain exercise.

Types of Exercise

Range-of-Motion Exercises

Passive range of motion involves no active contraction of the muscle. The joint is moved through a range of motion by another person or by an outside force. This type of exercise is often used to increase joint or muscular flexibility or to promote muscle relaxation. Active-assistive range of motion is performed with the assistance of a second person. The athlete uses muscle activity to move the part but is assisted by the practitioner. This type of exercise is often used when the athlete is unable to perform the exercise independently because of an injury or when independent exercise is contraindicated. Active range of motion is performed entirely by the athlete's own muscle power, with no assistance or resistance. This type of exercise can be used to increase the range of motion or for strengthening when resistance is not indicated. Active-resistive range of motion or strengthening is performed against resistance.

Strengthening

Strength is defined as the maximum amount of weight a muscle can move. Strengthening exercises employ resistance to increase the strength. *Resistance* is an outside force applied in a direction opposite to the motion of the body segment being exercised. The amount of resistance can be fixed or varied throughout the range or applied isometrically. Resistance can be applied in a variety of ways. The weight of the body or body segment can be used as resistance in an open- or closed-chain manner. Free weights, dumbbells, bar bells, cuff weights, and medicine balls provide a fixed amount of resistance in small increments. Elastic tubing or bands come in a range of levels of resistance that is somewhat variable through the range as the band is stretched. Manual resistance is provided by the contact of the practitioner's hand against the body segment.

Resistance can be provided by machines or weight stations. Weight increments are often larger than those available with other types of resistance. Weight can be fixed throughout the range of motion, or some systems attempt to vary the resistance throughout the range. *Progressive resistive exercise* (PRE) is a method of strengthening muscles used in rehabilitation settings, in which the resistance is added in selected increments in one session.

Isokinetic exercise is a type of strengthening exercise. Special equipment is required for this. The speed at which the exercise is performed is fixed, and the resistance varies throughout the range of motion.

Plyometrics are activities designed to develop explosive power in muscles, which is a component of strength in athletic activities. The muscle undergoes a repetitive, rapid, eccentric, or lengthening contraction, quickly followed by a rapid, concentric, or shortening contraction, such as jumping in place.

Flexibility

Flexibility refers to the amount of motion allowed by joint structures and the muscle tendon unit. Stretching exercises are usually done passively, with no activity in the muscle or muscle group being stretched. The muscle is placed in a position of stretch or elongation, and the position is maintained. This is called *static stretching*. Thirty seconds is the generally accepted time for holding the stretch to achieve maximum benefit. Bouncing or ballistic stretching is not recommended because it is not effective and may cause further injury. Rehabilitation professionals may employ a technique in which the muscle to be stretched performs an isometric or isotonic contraction first, followed by a stretch of the same muscle or group of muscles to increase flexibility.

Muscular Endurance

Muscular endurance is the ability of a muscle or a group of muscles to perform continuous activity without fatigue. Exercises are directed to specific muscles or muscle groups using low resistance and high repetitions.

Aerobic and Anaerobic Exercise

Cardiovascular endurance can be trained through aerobic activities, such as distance running. Aerobic exercise improves oxygen consumption of the body and typically involves repetitive exercise performed at a moderate intensity for an extended period of time. Guidelines usually suggest a total duration of 30 minutes. Intensity is defined as the target heart rate (THR). A lower THR is used for lower levels of fitness. THR is calculated by the following equations:

$$\text{Maximum heart rate} = 220 - \text{Age of athlete}$$

$$\text{THR} = 60\text{–}85\% \times \text{Maximum heart rate.}$$

The injured athlete can often engage in selected aerobic activities to avoid stress on the injured area and maintain cardiovascular endurance. Anaerobic exercises are performed at a higher intensity but for a much shorter duration than aerobic exercises—up to 2 minutes—and do not improve cardiovascular endurance.

Joint Stability and Balance

Joint stability refers to the ability of the various joint structures and the muscle-tendon unit to resist forces and therefore prevent injury. Proprioceptors are sensory receptors in the muscle-tendon unit and joint structures that provide information to the brain about the position of the limbs and body in space. These receptors, which can become faulty after an athletic injury, provide feedback to the brain, which then controls the response of the muscle to the force.

Balance refers to the static and dynamic components of movement. Many systems are involved with balance, including the proprioceptive, visual, and vestibular systems. Proprioceptive and balance activities include balancing with the eyes open or closed, using a progressively smaller base of support or using an unstable surface. Equipment includes foam surfaces or wobble boards.

Proprioceptive neuromuscular facilitation (PNF) is an example of an exercise technique used to enhance joint stability. PNF uses specific patterns of movement of entire limbs or body segments through a range of motion and may incorporate manual resistance.

Neuromuscular Coordination and Retraining

Neuromuscular training is used at all levels of rehabilitation. The process involves developing correct timing of muscle activation to produce correct execution of sports activities.

Sports-Specific Activities

Sports-specific activities are introduced during the latter stages of the rehabilitation process. Activities include drills that mimic the movements or activities involved in the sport. Gradual return to competition is recommended to allow time to recondition the athlete to the activity and prevent recurrence of the injury.

Christine Ploski and Michelina Cassella

See also Physical and Occupational Therapist; Principles of Rehabilitation and Physical Therapy; Resistance Training; Static Stretching

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Thigh Contusion

An injury to the front part of the thigh, usually from a direct blow to that area, is common in contact sports and should be recognized early. If the muscle trauma is severe enough, it can develop into a compartment syndrome, and if untreated, it can lead to muscle necrosis, fibrosis, and calcification (myositis ossificans). Treatment involves the use of the RICE principles (*r*est, *i*ce, *c*ompression, and *e*levation) and physical therapy. Recovery depends on the severity of the contusion but can take from days to weeks.

Anatomy

The *quadriceps* are a group of muscles on the front part of the thigh. They include four different muscles: (1) rectus femoris, (2) vastus lateralis, (3) vastus medialis, and (4) vastus interomedialis. Their main function is the extension of the knee (straightening of the leg).

History

A quadriceps contusion develops after a direct blow to the thigh. This can be seen in many contact sports (football, rugby, soccer, mixed martial arts). A *contusion* (bruising) is formed by the rupture or breaking of the blood vessels within the muscle

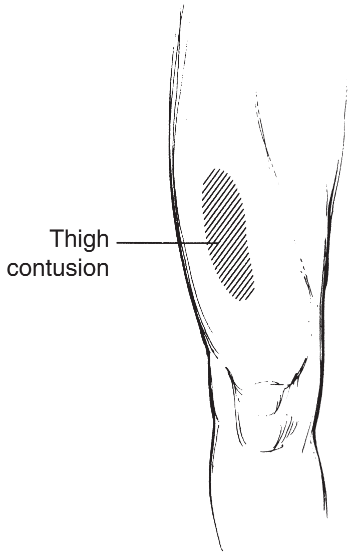

Figure 1 Thigh Contusion

Notes: A thigh contusion is caused by trauma and involves bleeding into the muscle fibers. Unlike strains, which affect the superficial muscles, such contusions occur deep inside the muscle, close to the bone.

(Figure 1). If the bleeding is severe enough, it can cause elevated pressure, which can compress the nerves and other blood vessels within that muscle compartment. This compression of nerves and blood vessels causes tissue death and is otherwise known as *compartment syndrome*. Compartment syndrome is rare in the thigh, but it does occur sometimes, so if this condition is suspected, the patient needs to be examined by a surgeon immediately.

Calcification of the muscle (*myositis ossificans*) can also occur if the athlete tries to rehabilitate a severe contusion too quickly. In this case, the bruised muscle grows bone instead of new muscle cells. Early recognition is the key to preventing this condition.

Symptoms

There will be tenderness at the site of the injury, as well as pain with knee flexion. There may or may not be swelling such that there is an increased circumference of the affected thigh. Sensation should be normal in the lower leg. If this not the case, then compartment syndrome should be considered. Contusions are categorized in three levels: Grade 1, Grade 2, and Grade 3 (most severe). Severity depends mainly on the degree of limited knee flexion (straightening) and on gait abnormalities (limping). Grading of the contusion is important to apply the appropriate treatment.

Imaging

Imaging studies are usually not needed initially for the diagnosis of quadriceps contusions. A diagnosis can usually be made by history and physical exam alone. X-rays are beneficial to look for any fractures of the femur (thighbone) or patella (kneecap), or bone formation in the muscle (myositis ossificans). Ultrasound is a good, inexpensive tool to look for complete muscle tears, but it is not as good for partial tear diagnoses. Magnetic resonance imaging (MRI) is considered the best imaging tool for soft tissue pathology.

Treatment

As soon as a quadriceps contusion is recognized, the athlete should be put into 120° of flexion (knee bent) for at least the first 10 minutes but should not sustain that position for more than 24 hours. This position helps in many ways: It limits the amount of muscle spasm and bleeding into the muscle, decreases the risk of developing bone formation in the muscle, and decreases the amount of pain experienced at that time. Crutches may be necessary early on if walking generates pain. The general RICE principles are applied: *r*est, *i*ce 15 to 20 minutes every 2 to 3 hours, *c*ompression of the thigh with an elastic wrap as needed for swelling, and *e*levation of the leg to decrease swelling. Applying heat should be avoided because this can cause an increase in swelling. Once the pain has been resolved, the athlete should work on stretching, strengthening, and increasing range of motion of the quadriceps and hamstrings (a group of muscles on the back portion of the thigh). Nonsteroidal anti-inflammatory drugs (NSAIDs) such as ibuprofen are often recommended initially for the first few days after onset of injury along with the RICE therapy. They help not only with pain control but also with swelling.

If compartment syndrome does occur, the athlete must be evaluated by a surgeon immediately. A fasciotomy (opening of the compartment) is necessary for treatment. If this is left untreated, the muscle tissue breaks down, which can lead to muscle contractures.

Myositis ossificans can occur in up to 9% of quadriceps contusions. This condition does not develop acutely and usually occurs approximately 3 months after the injury. Initial treatment includes conservative measures such as oral anti-inflammatories, massage, and stretching. If severe pain persists months after this onset, then surgery is recommended.

Prognosis

The athlete's return to play varies depending on the severity of the quadriceps injury. The athlete may resume play once 120° of flexion is achieved painlessly and there is no evidence of quadriceps weakness or atrophy. Protective padding is recommended for the injured area for the rest of the season.

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See also Compartment Syndrome, Anterior; Thigh Injuries

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Thigh Injuries

Injuries to the anterior and posterior thigh are fairly common in sports, particularly in running and jumping sports. Particularly common are *muscle strains* and *contusions*. Quadriceps strains are common in running, jumping, and kicking sports, such as track-and-field events, basketball, and soccer. Hamstring strains occur frequently in sports involving high-speed running and kicking, such as sprints, hurdles, long jump, football, and field hockey. In Australian football, hamstring injuries account for 15% of all injuries and are the most common and prevalent injury. Likewise, in British soccer, hamstring injuries constitute 12% of all injuries. These injuries also have the highest recurrence rate (34% in Australian football, 12% in British soccer). Quadriceps contusions, commonly known as a "charley horse," are extremely common in contact sports such as football and basketball and in ball/puck sports such as hockey, lacrosse, and cricket.

Anatomy

The femur is the only bone in the thigh. The quadriceps muscle group in the anterior thigh contains the rectus femoris, vastus lateralis, vastus medialis obliquus, and sartorius. They are the strongest muscles in the anterior thigh and function to extend the knee. The hamstring muscle group in the posterior thigh consists of the biceps femoris, the semimembranosus, and the semitendinosus. The biceps femoris has two heads. The short head acts only on the knee and is innervated by the common peroneal nerve, whereas the long head is innervated by the tibial portion of the sciatic nerve. The hamstrings cross two joints and are responsible for hip extension and knee flexion. The semitendinosus, the semimembranosus, and the long head of the biceps originate on the ischial tuberosity.

The adductor magnus functions in hip extension and adduction and is innervated by the tibial portion of the sciatic nerve, like most of the hamstring muscles. The posterior part of the adductor magnus is sometimes considered functionally to be part of the hamstring group because of its anatomical position.

Evaluation of Injuries

Details of Injury

The exact location of pain and the mechanism of injury in the setting of a thigh injury can help in diagnosis. In the case of contusions (bruises) or muscle strain, the site of pain is usually well localized. Contusions of the anterior thigh are most common in the anterolateral aspect of the thigh or in the vastus medialis obliquus, although they can occur anywhere.

The mechanism of injury can usually differentiate between muscle strains and contusions. Muscle strains usually occur when the athlete is striving for greater speed while running or extra distance while kicking. The athlete usually remembers a specific event that causes pain and some immediate functional limitations. A contusion, however, is usually the result of a direct blow. The athlete's age and skeletal maturity may affect the type of injury seen, as injury patterns in adolescents differ from those in adults, such as avulsion fractures, seen in younger patients with open apophyses.

With severe injuries to the thigh, the athlete may not be able to continue the sporting activity. The athlete may be unable to go back to sports and may be unable to walk or run without pain. There may be swelling and bruising at the site of injury. Injuries to the thigh should initially be treated with the RICE (*r*est, *i*ce, *c*ompression, and *e*levation) regimen to decrease swelling. Factors such as hot showers/baths, heat rubs, excessive activity, or alcohol ingestion may worsen thigh injuries and prevent healing.

Certain sports make thigh injuries more likely, such as soccer, football, and hockey. Recent changes in the training regimen may contribute to injuries. Previous thigh injuries may predispose an athlete to recurrent injuries. The athlete's age is also important, as during periods of growth, children and adolescents may have muscle inflexibilities and muscle imbalances that may predispose them to thigh injuries.

Anterior or thigh pain that has a gradual onset and is poorly localized may indicate a stress fracture or possible tumor. If anterior or posterior thigh pain is variable, is poorly localized, and lacks specific aggravating factors, the pain may be referred. Bilateral thigh pain is usually referred from the lumbar spine. A high index of suspicion and an understanding of what structures can refer pain to the posterior thigh are essential to make the correct diagnosis. Any "red flag" symptoms, such as night pain, night sweats, weight loss, or neurological symptoms such as numbness or tingling, may indicate infection or cancer as a cause of thigh pain.

Physical Findings

In acute injuries of the thigh, the diagnosis is usually straightforward, and the injury is usually limited to local structures. When pain is more insidious, the cause of the injury may be less straightforward and may be referred from the hip, sacroiliac joint, or lower back.

Thigh injuries may result in bruising, swelling, atrophy, or other deformity to the anterior or posterior thigh. Comparing the injured leg with the uninjured leg can highlight any abnormalities. Athletes with thigh injuries may walk with a limp and be unable to move the leg normally. The range of motion of the hip and knee may be affected. With anterior thigh injuries, stretching of the quadriceps muscle (the athlete lies on his or her stomach and tries to bring the heel of the foot to the buttocks) may be decreased or may cause pain. With posterior thigh injuries, stretching the hamstring muscles (the athlete lies on his or her back and raises the affected leg to the point of pain and then to the end of range) may cause pain.

Thigh muscle strength may be decreased secondary to injury. The athlete may have muscle weakness or pain when trying to resist certain movements. For instance, with quadriceps injuries, the athlete may be unable to extend the knee against resistance when sitting with the hip and knee flexed to 90°. Similarly, the athlete may be unable to flex the hip against resistance. With hamstring injuries, an athlete may be unable to flex the knee against resistance while lying on the stomach. The athlete may be unable to squat, jump, hop, run, or kick secondary to pain or weakness.

Thigh injuries may be accompanied by tenderness, swelling, or defects in the muscle belly. Defects in the muscle belly may be more pronounced when the affected muscle is contracted. The origin of the hamstring at the ischial tuberosity may also be tender with hamstring injuries. In addition, the muscles of the buttocks (gluteal muscles) may be tender to palpation.

A stress fracture of the femur may cause pain in the thigh when a fulcrum test is performed. With the athlete sitting on the edge of the bed and the legs hanging over the edge, the examiner applies pressure over the distal femur. Reproduction of the athlete's pain in the thigh with this maneuver is suggestive of a stress fracture.

Sometimes thigh pain is related to a neurological problem. Certain tests, called *neural tension tests*, can help determine if the thigh pain is caused by damage to the nerves. With anterior thigh pain, a modified Thomas test can be performed with the patient supine and the legs off the end of the bed. The patient flexes the cervical and upper thoracic spine as the examiner passively flexes the patient's knee while extending the other leg. Reproduction of the patient's symptoms indicates nerve involvement. For posterior thigh pain, a slump test can be performed with the patient sitting on the edge of the end of the bed. The examiner flexes the patient's cervical and upper thoracic spine and then extends the patient's leg. Reproduction of symptoms suggests a neural component.

Investigations

In athletes with anterior thigh pain, investigations are usually not necessary. X-rays may indicate myositis ossificans (calcification of the muscle) in a quadriceps contusion that is not getting better. Ultrasound will confirm the presence of a hematoma and may show early calcification. Stress fractures may also be shown on X-rays. If X-rays are negative, bone scan should be performed.

If thigh pain is associated with an abnormal hip examination, hip X-rays should be obtained (Table 1). In adults, there may be evidence of arthritis. In younger patients, Legg-Calvé-Perthes disease or slipped capital femoral epiphysis may be shown.

Prevention of Injury

Many acute thigh injuries can be prevented with appropriate stretching, adequate strengthening, and proper warm-up. The proper safety equipment for the particular sport should be worn and properly maintained. Additionally, playing with athletes at the same skill level can help prevent acute injuries. Prevention of chronic thigh injuries can be achieved by instituting appropriate training programs and avoiding training errors. Common training errors include inappropriate progression of the rate, duration, and intensity of training.

Table 1 Common Anterior and Posterior Thigh Injuries

	Common	*Uncommon*	*Must Not Be Missed*
Anterior	Quadriceps contusion	Femoral stress fracture	Legg-Calvé-Perthes disease
	Quadriceps strain	Sartorius/gracilis muscle strain	Slipped capital femoral epiphysis (SCFE)
	Myositis ossificans	Rectus femoris apophysis avulsion	Tumors
		Referred pain (lumbar spine, sacroiliac joint, hip joint)	
Posterior	Hamstring muscle strain	Bursitis	Tumors
	Hamstring muscle contusion	Tendinopathy	
	Referred pain (lumbar spine)	Apophysitis/avulsion fracture of ischial tuberosity	
		Adductor magnus strains	
		Myositis ossificans	
		Nerve entrapments	
		Referred pain (sacroiliac joint)	

Targeting anatomical risk factors such as lower extremity alignment, muscle imbalances, poor conditioning, and inflexibilities can also help decrease thigh injuries. Other risk factors that should be addressed include inappropriate footwear, playing surfaces, and nutrition.

Return to Sports

For most minor injuries of the thigh, such as strains and contusions, a period of rest followed by appropriate therapy emphasizing stretching and strengthening will allow athletes to regain flexibility and strength. Before returning to sports following a thigh injury, strength and flexibility should be back to 80% to 90% of normal to prevent recurrent injury and allow effective movement. Pain should also have resolved. Regular physiotherapy can help monitor progress and determine the athlete's readiness to return to play. Following more serious thigh injuries, such as acute fractures and stress fractures, return to play should be delayed until pain has resolved, there is radiological evidence of healing, and risk factors have been addressed and modified.

Laura Purcell

See also Hamstring Strain; Quadriceps Strain; Slipped Capital Femoral Epiphysis; Thigh Contusion; Thighbone Fracture

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Thighbone Fracture

Thighbone fracture refers to fractures of the femur, the sole bone in the thigh. They are caused by high-energy trauma or overuse. This entry reviews the basic types of fractures of the femur, fracture healing, fracture treatment methods, and general outcomes.

Fracture Types

Thighbone (femur) fractures are described by where they are located, how much out of place the bone is, and whether the bone has broken through the skin. In lay terms, it is sometimes assumed that a break is more serious than a fracture; to a physician, both refer to the same thing. A fracture that is incomplete, or not fully through the bone, may be called a *stress fracture.* This can occur in a runner from overuse, for example. A complete fracture, which is fully through the bone, may be described as either *nondisplaced* (hairline crack) or *displaced* (two parts not aligned), ranging from minimally displaced to widely displaced. *Comminuted fracture* refers to a bone being broken in many pieces rather than cleanly. The older term for a broken bone that went through the skin was *compound fracture;* now this is described as an *open fracture.* A fracture that does not pierce the skin is *closed.* Thus, when we say that a person has an open, widely displaced comminuted femur fracture, we mean that the person has a thighbone fracture that is badly out of place and the bone has broken in many pieces and gone through the skin.

In general, most thighbone (femur) fractures are caused by high-energy trauma. Thus, associated injuries in other parts of the body must be looked for too. For example, in a person involved in a high-speed motor vehicle collision, there may be internal bleeding and head injuries along with a thighbone fracture. These need to be managed first.

Fracture Healing

Thighbone fracture healing varies by age of the patient, location and severity of the fracture, and treatment method. In general, children's bones heal much faster than those of adults. In a baby a thighbone may heal in 1 month, while in a 6-year-old the same bone may take 6 weeks and in an adult 6 months to fully heal. When a bone fractures, first a blood clot forms, much like a scab forms on cut skin. Next, the cells in the blood clot recruit bone-forming cells (*osteoblasts*), which begin making new bone. At first, this bone is poorly organized and looks cloudy on an X-ray. This is called *callus*. Usually, the presence of callus allows weight bearing by 6 weeks after the fracture. Over time, this new bone solidifies and reorganizes into strong new bone. This is called *remodeling*. This takes from several months to several years after the injury. In children particularly, bones have wonderful remodeling properties. It is possible for a child to have a bone heal very crookedly at first and then straighten itself out without help over time. Good nutrition, in particular vitamin D (400 international units [IU]/day) and calcium (1,000 milligrams per day), is also very important for fracture healing.

Fracture Treatment Methods

Thighbone fracture treatment varies widely by the age of the patient and the severity of the injury. For a stress fracture (incomplete break in the thighbone), crutches may be all that is needed. For more severe fractures, surgery with rod or plate and screw fixation may be needed. The guidelines for fracture treatment are reviewed below.

Initial Treatment

The initial treatment when someone is injured should be to assess the injury and to stabilize the injured part, straightening it gently if it is bent or twisted. A removable stabilizing device, or splint, is applied. If an open fracture is present, the bone should not be put back through the skin. Instead, a clean dressing should be applied as well as a splint, and urgent transport to a medical center should be arranged. The portion of the leg below the thighbone fracture should be assessed for vascularity and nerve function by checking that the toes can move and are pink and warm. After the initial immobilization, the patient should be assessed by a physician. As thighbone fractures are generally the result of high-energy trauma, transport is generally by ambulance from the accident scene to the emergency room. Generally, X-rays are obtained, and sometimes other studies, such as computed tomography (CT) and magnetic resonance imaging (MRI) scans, are done to determine what kind of fracture is present. Once the fracture has been properly diagnosed, treatment can proceed. If other, more severe injuries are present, these are diagnosed and treated first.

Definitive Treatment

Stress Fractures

These are generally treated nonoperatively with rest, protected weight bearing, and time. For example, a (nondisplaced) stress fracture in the thighbone usually requires the use of crutches and should have no weight on it for 6 weeks. Some stress fractures at the top of the thighbone (hip area/femoral neck) may need screw fixation because of the high risk that they may break all the way through.

Displaced Fractures

Thighbone fractures that are out of place generally need to be straightened (this is called *reduction*) and may need surgery. In babies less than 6 months old, thighbone fractures may be treated in a soft brace called a *Pavlik harness*. In children aged 6 months to 6 years, displaced thighbone fractures can often be treated successfully with reduction and body casting (called a *spica*) for 6 to 12 weeks. In older children and adults, displaced thighbone fractures need surgical fixation for treatment. Fixation may be external fixators (pins that come out through the skin and hold the bone in place by attaching to a bar), plates and screws, or rods put down the hollow middle part (*medulla*) of the thighbone. Most adult thighbone fractures are treated with a strong rod down the middle of the bone. In image (a) on page 1479, a thighbone fracture X-ray is seen. In images (b) and (c), the fracture has been treated with a rod and has healed with a lump of new bone (callus). In severe injuries, the thighbone may be temporarily stabilized with an external fixator; then in a later surgical procedure, a rod or plate and screws may be applied.

Open Fractures

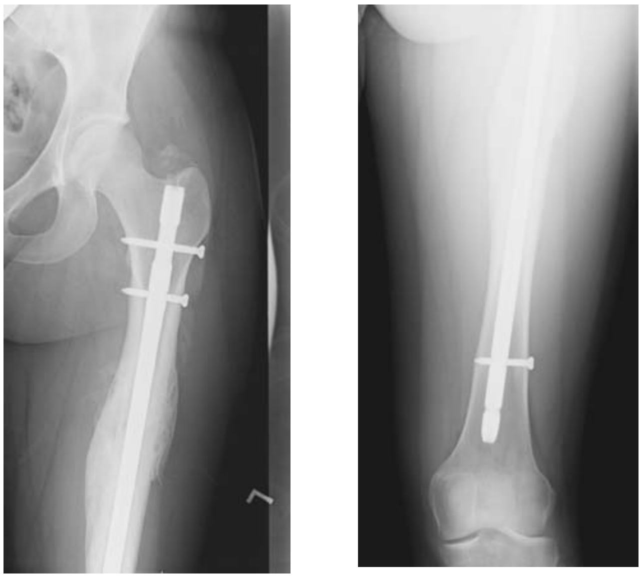
Fractures that come through the skin always need surgery to clean them. This is because they are at high risk of infection. After the surgical cleaning, the bones are fixed using the method most appropriate for the type of fracture.

(a)

Thighbone fracture.

Source: Photo courtesy of Children's Orthopaedic Surgery Foundation.

(b) (c)



Thighbone fracture with callus formation after treatment with a rod; (b) thighbone fracture after rodding with healing new bone (callus) and (c) lower end of the same thighbone with rod after healing

Source: Photo courtesy of Children's Orthopaedic Surgery Foundation.

Rehabilitation

If a thighbone is treated with a rod, immediate weight bearing with crutches is allowed. Early bone healing is present at 6 weeks, but it may take 4 to 6 months for the bone to fully solidify. Contact sports are not allowed until the bone is solidly healed. Rehabilitating the thigh muscles is equally important and often takes at least as long as the bone healing time. Usually, this involves physical therapy. A physical therapist is someone trained to guide patients through exercising the injured part according to their doctor's orders until return of full strength and function. After a high-energy thighbone fracture, it is often 4 to 6 months before patients can return to any sport. Limping may persist for 6 months to a year as well. In adults, the thighbone rods or other fracture fixation devices are usually left in place permanently unless they are bothersome, in which case they can be surgically removed. In children, some fracture fixation devices may need to be removed, while others may be left in place.

Outcomes

Most patients with thighbone fractures will go through a normal healing process, and the bone will return to a high functional level. Thus, most athletes sustaining a thighbone fracture can expect to return to their sport. However, some permanent quadriceps muscle weakness may be present, especially in severe fractures.

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See also Football, Injuries in; Rugby Union, Injuries in; Skiing, Injuries in; Sports Injuries, Acute

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Thumb Sprain

A *thumb sprain* is a stretch or tear of a ligament located at one of the thumb joints. This traumatic injury is common, and athletes in sports such as skiing, football, and wrestling are frequently affected. In fact, in skiers, only the knee is injured more often than the thumb. This condition not only leads to time lost from sports until it is healed, but it also creates the potential for future disability if it is not properly identified and treated.

Thumb sprains can occur at any of the three thumb joints. A thumb sprain however, is synonymous with an injury to the inside ligament (ulnar collateral ligament, UCL) at the middle joint (metacarpophalangeal, MCP) of the thumb. Multiple names are used to describe UCL sprains, including "gamekeeper's thumb" and "skier's thumb." The term *gamekeeper's thumb* was coined after Scottish gamekeepers (ca. 1955) were found to be prone to these particular thumb sprains. Their repetitive practice of breaking the necks of small game by holding the animal in the web space between their thumb and pointer finger would injure the UCL. In recent times, this injury has been more commonly referred to as skier's thumb. Relatively frequent trauma and subsequent falls create a strong correlation between skiers and thumb sprains.

Anatomy

The thumb is composed of three bones and three joints. The bones of the thumb are the metacarpal, proximal phalanx, and distal phalanx. The metacarpal bone is the one closest to the wrist, the distal phalanx is at the tip of the thumb, and the proximal phalanx lies between these two bones. Connecting the thumb bones from the wrist to the tip of the thumb are the carpometacarpal (CMC), MCP, and interphalangeal (IP) joints, in that order. At each joint, there are multiple ligaments that provide stability to the thumb when traumatic or pinching forces are placed on it. They are the collateral ligaments, the volar plate, and the joint capsule. The collateral ligaments are located on the inner and outer sides of each thumb joint and provide side-to-side stability. The UCL is the collateral ligament closest to the little finger, and the radial collateral ligament (RCL) lies on the opposite side of the joint from the UCL. The volar plate is a ligament located on the palm side of each thumb joint and prevents hyperextension. Finally, the joint capsule is a saclike envelope that encloses the entire joint.

Type of Injury

The majority of thumb sprains occur at the UCL of the MCP joint. The second most common sprain occurs at the RCL of the MCP joint. The IP joint infrequently experiences ligament injury. Rarely are there isolated injuries to the CMC joint. The ligaments at this joint are well protected from trauma. Certainly, fractures and dislocations are associated with ligament sprains, but they are beyond the scope of this entry.

Clinical Evaluation

History

There are numerous traumatic mechanisms that can cause a thumb sprain. All, however, involve a side-to-side force that creates extreme thumb movement either toward or away from the hand. The collateral ligaments are naturally affected as they provide side-to-side stability at the thumb joints. Typical examples of these movements are a fall while holding a ski pole or a fall onto an outstretched and extended thumb.

After a thumb sprain, athletes will experience immediate pain and swelling at the joint. Activities such as pinching and gripping of the thumb will produce pain. If the injury is old and has not been treated, pinching weakness and degenerative arthritis are possible long-term complications. This weakness and instability can be debilitating in those sports that require strong pinching and grasping abilities.

Physical Examination

Swelling and bruising are common findings on physical examination. A finding of localized tenderness over a specific side of the joint is important in isolating the affected collateral ligament. Stress testing is used to assess ligament stability. This involves applying a bending stress to the ligament at 0° and 30° of flexion. When a ligament is completely torn, the joint will significantly "open up" as there is no ligamentous integrity to resist the stress testing. If there is only a partial tear or stretch, the ligament will withstand the applied stress and prevent the joint from moving. It is vital that stress testing is performed on both symptomatic and asymptomatic thumbs to compare results. Patients can have wide variations in their amount of normal joint laxity (looseness).

Diagnostic Tests

Obtaining plain radiographs is a routine part of evaluating a thumb sprain. An avulsion fracture has been found to be associated in 20% of ligament sprains. Some physicians advocate stress X-rays in addition to normal radiographs when the history and physical exam do not reveal a clear diagnosis. Stress X-rays look at the affected joint while a stress is applied similar to the physical exam maneuver above. These views provide additional information as to whether the thumb ligament is partially or completely torn. The benefit and accuracy of magnetic resonance imaging (MRI) in further defining the ligaments of the thumb have not been conclusively determined.

When significant ligamentous laxity is found on physical examination, the joint is said to be unstable, which likely indicates a complete rupture of the ligament. This raises the suspicion that a unique injury to the UCL, called a Stener lesion, is present. A Stener lesion occurs when the UCL tears and the surrounding tissue of an overlying thumb tendon gets lodged between the torn UCL fibers. Subsequently, the UCL is unable to come together and heal due to the interposed soft tissue. In addition to unstable stress testing, a Stener lesion is infrequently identified on physical examination as a mass on the hand side of the MCP joint. Unfortunately, the best way to visualize a Stener lesion is during surgery.

Treatment

The management of thumb sprains is divided according to the stability of the affected ligament. Stable thumb sprains are typically treated nonoperatively, while unstable thumb sprains are treated with surgery. Stener lesions are included in the unstable category and require operative intervention at the UCL.

Nonsurgical Treatment

Initial care of a thumb sprain includes rest, ice, elevation, and over-the-counter pain medication. If available, protection with a splint is helpful to control pain symptoms and reduce motion at the affected thumb joint. When the sprain has been determined to be stable according to the medical evaluation, the athlete is immobilized in a splint or cast that covers the thumb. At periodic follow-ups, the athlete's tenderness to palpation and joint stability are assessed. The thumb is typically immobilized for 4 to 6 weeks until the patient is nontender and the joint is stable. Rehabilitation for the wrist and thumb is often started at approximately 4 weeks with range-of-motion (ROM) and strengthening exercises. This is continued until full ROM and strength are achieved.

Surgery

Surgery of a thumb sprain typically consists of a primary repair. This refers to the reattachment of the two ends of the torn ligaments. A primary repair is most successful soon after the injury. In general, completely torn thumb ligaments can usually be repaired by 6 to 8 weeks after the date of injury. After surgery, the athlete will be immobilized for a period of time and then progressed to a rehabilitation program similar to the one described above.

When operative intervention is delayed or the athlete is not evaluated for a thumb sprain, there is a higher likelihood that the ligament is going to scar and shrink in size. As a result, the ligament ends become very difficult to sew back together beyond the 6-week time period. When this happens, more complicated surgeries are required for successful treatment. They include a reconstruction, where a portion of tendon from another body part is substituted to make a brand new ligament. The other option for delayed treatment is a fusion of the joint. This, however, may be optimally done after the athlete's athletic career is completed.

Return to Sports

Those athletes who are immobilized with a splint or a cast may be able to return to their sport as soon as their symptoms are controlled. In certain sports, athletes are allowed to compete while casted. For example, football players are allowed to participate with a splint or a cast if it is properly padded.

For the athlete who is unable to compete with a splint or a cast, a rehabilitation program is continued after immobilization. When full ROM and strength are achieved, sport-specific drills and a return-to-play progression are begun. For most sports, taping of the MCP joint to the index finger (buddy taping) should continue for up to 12 weeks after the injury.

Samuel Bugbee and Tracy Casault

See also Finger Sprain; Hand and Finger Injuries; Hand and Finger Injuries, Surgery for; Skiing, Injuries in

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Tibia and Fibula Fractures

The tibia and fibula, the two long bones of the lower leg, can be fractured during sporting activities. Although isolated fracture of either the tibia or the fibula can occur, most often both bones are fractured in the same injury. Early diagnosis and immediate treatment with splint immobilization are necessary for patient comfort and treatment. Emergent follow-up with an orthopedic surgeon is necessary to evaluate the patient and definitively treat the fracture(s).

Anatomy

The tibia, commonly called the shinbone, is the major weight-bearing bone of the lower leg. The part of the tibia that articulates with the femur at the knee is called the *tibial plateau,* the middle is the *tibial shaft,* and the lower portion, which articulates with the ankle joint, is called the *tibial plafond.* The inner aspect of the ankle bone that can be felt is part of the tibia and is called the *medial malleolus.*

The fibula is the smaller bone on the outer part of the leg. The part near the knee is called the fibular head, the middle is the shaft, and the part that articulates with the ankle is called the *lateral malleolus.*

The tibia and fibula are connected by the interosseous membrane, a broad plane of fibrous connective tissue, and multiple ligaments at the knee and ankle.

There is only a small amount of soft tissue between the tibia and the skin, which is the cause of many open tibia fractures. An *open fracture* occurs when the energy from the injury forces the bone through the skin. The fibula has more soft tissue surrounding it, so a fracture is less likely to be open. The exception to this is at the ankle, where the lateral malleolus is just underneath the skin, with a thin soft tissue layer.

Causes

Sports-related fracture of the tibia and fibula is a relatively low-energy injury. The fracture can occur from a direct blow on either side of the lower leg or by landing hard on the foot of the fractured leg. Additionally, a severe twisting injury can fracture the tibia and fibula.

Symptoms

Pain, swelling, inability to walk, and deformity are common signs and symptoms of tibia and fibula fractures. With an isolated fibula fracture, the athlete is often able to walk or run; therefore, the diagnostic process is much more difficult.

Diagnosis

The diagnosis of a tibia or fibula fracture can often be made based solely on history and physical exam. There is often gross deformity of the lower leg associated with bruising, swelling, tenderness, and occasionally a skin opening or laceration with protruding bone—clearly indicating an open fracture. Palpation along the tibia can reveal crepitance or gross movement of the bony fragments. During the physical exam, it is important to examine the knee for an effusion, and a detailed neurovascular exam of the foot is imperative. The neurovascular exam should include motor (wiggling of the toes) and sensory (testing whether the athlete can feel you touching his or her toes and heel) exams, as well as palpation of the dorsalis pedis and posterior tibial pulse and checking capillary refill. Along with the history and physical examination, radiographs including an anterior-posterior (AP) view and a lateral view can clinch the diagnosis. X-rays of the knee and ankle joint are recommended as well.

There are three types of tibial shaft fractures:

1. *Transverse:* straight perpendicular to the axis of the bone
2. *Spiral:* in a spiral pattern down the bone
3. *Oblique:* at an angle to the axis of the bone

For comminuted (multiple fracture fragments) tibial plateau and tibial plafond fractures (fractures that go into the joint surface of the knee and ankle, respectively), a computed axial tomography (CAT or CT) scan of these areas is often useful to further classify the fracture pattern for preoperative planning.

Treatment

After a thorough history and physical exam, the initial treatment of any tibia or fibula fracture includes reduction (if needed) and immobilization of the lower leg with a splint. Emergent reduction by a trained professional is needed if the athlete has a gross deformity or does not have a pulse in his or her foot or if the foot is discolored. If the athlete sustains an open fracture, a sterile dressing should be applied to the wound, and the leg should then be immobilized. In an appropriate setting (emergency department), the athlete's open wound should be irrigated with sterile saline solution and dressed with a sterile dressing. The athlete should also receive a tetanus booster, if not up-to-date, and intravenous antibiotics immediately in the emergency department and for several doses. The specific antibiotic(s) to be given should be decided on by the orthopedic surgeon and is determined by the severity of the injury and the contamination within the wound.

After reduction and/or wounds are addressed, the athlete should be placed in a long leg splint (from midthigh to the ends of the toes). There are a variety of splinting materials (prefabricated metal splints, plaster, orthoglass, inflatable plastic splints, etc.) that are available, and any form of immobilization will work in the emergent setting. It is important that the splinting material not wrap all the way around the leg and the leg not be wrapped tightly. Also, access to the foot and calf should be available to frequently check for pulses and check the leg for developing compartment syndrome. Compartment syndrome occurs when swelling increases the pressure in the leg compartments to the point where it exceeds the pressure needed to get blood to the muscles and nerves within the compartment. This leads to nerve and muscle death if not treated emergently with a surgical release of the involved compartments, called a fasciotomy. Compartment syndrome is an orthopedic emergency and is common in the setting of tibia and fibula fractures. Please see the entry Compartment Syndrome, Anterior for signs, symptoms, and treatment.

After immobilization, the athlete should be taken to the emergency department for an orthopedic evaluation and definitive management. Ice application and elevation are extremely important treatment modalities for all fractures and should be implemented immediately and used consistently for the first few days after injury.

Nonoperative Treatment by Fracture Type

Closed fractures of the tibia and fibula may be treated with conservative care and nonsurgical treatment. The question of surgical versus nonsurgical care for a specific fracture is decided by the orthopedic surgeon. The following are some conservative treatment modalities for the different types of tibia and fibula fractures.

Tibial Plateau (Knee Joint Surface of the Tibia). Nondisplaced or minimally displaced fractures (bony pieces touching or very close together in anatomical alignment) can be treated by keeping the athlete non–weight bearing in a knee immobilizer or hinged knee brace. Early ROM exercises and quadriceps muscle strengthening are encouraged. Partial weight bearing (~50% of the athlete's weight) is allowed at 8 to 12 weeks from the injury, with progression to full weight bearing as tolerated.

Tibial Shaft. Nondisplaced or minimally displaced fractures can be treated initially in a long leg splint. The athlete's knee should be flexed from 30° to 60° degrees so that he or she can ambulate with crutches. The athlete will be non–weight bearing for 4 to 6 weeks.

Two weeks after injury, the patient may be transitioned over to a long leg cast if the swelling has subsided. Four to six weeks after injury, transition to a short leg cast (below the knee) is permitted. Weight bearing is progressed in the short leg cast for an additional 4 to 6 weeks. The healing time for tibial shaft fractures is highly variable, with an average time of 16 ± 4 weeks. Fracture braces can be also used to give support while the fracture heals.

Fibular Shaft. Treatment is weight bearing as tolerated. The tibia is the main weight-bearing bone of the lower leg; therefore, a splint, cast, or brace is not necessary for healing. A short period of immobilization (below the knee) may be used to help minimize the pain.

Tibial Plafond (Ankle Joint Surface of the Tibia). Most of these fractures require surgery, even if the fracture is nondisplaced. However, if nonsurgical treatment is elected, the athlete is made non–weight bearing and placed in a long leg splint/cast for 6 weeks. Six weeks after injury, a fracture brace with physical therapy for ROM and strengthening is used, and weight bearing is progressed as tolerated once there is radiographic evidence of healing.

Surgical Treatment by Fracture Type

Open fractures of any type require irrigation and debridement under sterile conditions in the operating room. Irrigation involves washing the fracture and the wound with sterile saline, with or without antibiotics in the solution. *Debridement* is the removal of all debris, such as grass, mud, pebbles, and any dead tissue, from the wound. This should be continued until the wound is cleaned of all possible sources of infection.

Tibial Plateau. Displaced fractures need to be fixed with open reduction and internal fixation, meaning surgical incision, reduction of the fracture, and insertion of plates and screws to hold the pieces of bone together in anatomic alignment. The main goal is to reconstruct the articular surface of the knee. The surgeon may use bone graft or cement to fill any voids and add strength if he or she feels that it is indicated. If the fracture pattern is highly comminuted (lots of small pieces), the surgeon may elect to use an external fixator, which involves placing pins into the bones and bars outside the skin to hold the fracture in anatomic alignment.

Tibial Shaft. Depending on the fracture pattern (transverse or oblique), the amount of comminution, and the fracture location (*proximal,* closer to the knee; middle; or distal, closer to the ankle), the surgeon may choose to use an intramedullary nail, plates and screws, or an external fixator to hold the fracture in anatomic position. An intramedullary nail is a titanium nail introduced through an incision at the knee and placed through the center of the proximal tibia, past the fracture site, and into the distal tibia. Screws are then placed in the proximal and distal tibia so that the nail cannot rotate. External fixation is described above. The fibula fracture is usually not operatively fixed with instrumentation. By fixing the tibia, the fibula is kept in an appropriate position to heal. Since it is not the main weight-bearing bone and it is surrounded by soft tissue, it usually heals without the need for operative fixation.

Fibular Shaft. Isolated fibular shaft fractures rarely need operative intervention. If the fibular shaft fracture is coexisting with an ankle ligament injury (e.g., syndesmosis injury), the surgeon may opt to perform open reduction internal fixation.

Tibial Plafond. The goals of surgery are to maintain fibular length and restore the tibial ankle joint surface. Often, final surgery is delayed for several

(7–14) days to give time for the swelling around the ankle to decrease. The athlete may be placed in a long leg splint and sent home with strict instructions to ice and elevate the ankle at all times until the swelling decreases. Alternatively, the athlete may have staged surgeries with external fixation placement immediately after the injury, with or without open reduction and internal fixation (plates and screws) of the fibula fracture. The athlete then rests with the ankle iced and elevated until swelling is decreased. At that time, the athlete will return to the operating room to have open reduction and internal fixation of the tibial plafond and removal of the external fixator. Bone graft, bone graft substitutes, or cement may be used as necessary. A short leg splint is applied in the operating room after surgery. An external fixator may be used as definitive treatment depending on the fracture type and soft tissue status.

Postoperative Care by Fracture Type

Tibial Plateau. As in nonsurgical treatment, the athlete will be non–weight bearing in a knee immobilizer or hinged knee brace. Early range-of-motion exercises and quadriceps muscle strengthening are encouraged. Partial weight bearing (~50% of the athlete's weight) is allowed at 8 to 12 weeks from the injury, with progression to full weight bearing as tolerated.

Tibial Shaft. No splint/cast is needed; an intramedullary nail or external fixation is used; then a splint/cast may be used after the use of plates and screws. The surgeon will determine the athlete's weight-bearing status based on the fracture pattern and the type of fixation used. Again, average healing time is 16 ± 4 weeks.

Fibular Shaft. This fracture, too, rarely requires an operation, but a splint/cast may be used after the use of plates and screws. The surgeon will determine the athlete's weight-bearing status based on the fracture pattern and fixation type.

Tibial Plafond. The athlete will be non–weight bearing for 12 to 16 weeks. Initially, the athlete will be in a short leg splint and will transition to a short leg cast in 2 weeks. In 4 to 6 weeks, the athlete may be transitioned to a fracture brace/boot, and physical therapy range-of-motion exercises will be started to decrease the stiffness in the ankle. After 12 to 16 weeks, progression will be made to weight bearing as tolerated once there is radiographic evidence of healing.

It is important to closely monitor the athlete's neurovascular exam status after all types of surgery to avoid the complications of compartment syndrome.

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See also Compartment Syndrome, Anterior; Lower Leg Injuries; Skiing, Injuries in; Sports Injuries, Acute

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Tibia and Fibula Stress Fractures

Stress fractures in the tibia and fibula are common in athletes. It has been reported that nearly 50% of stress fractures in the lower extremity occur in the tibia and up to 20% in the fibula. Sports such as cross-country and track account for a large number of these stress fractures, but any sports requiring repetitive running and jumping can result in a stress fracture of the lower extremity.

Most tibia stress fractures occur in the posterior medial tibia. Anterior tibia stress fractures are considered to be problematic, often needing a prolonged period of nonoperative treatment or surgical management to allow them to heal. Fibula stress fractures tend to occur about 5 to 6 centimeters above the lateral malleolus in athletes, but they can occur at any point along the fibula.

Pathophysiology

Many risk factors have been implicated in the development of stress fractures of the tibia and fibula. Some proposed risk factors include running surfaces, footwear, mileage, weight loss, osteopenia/osteoporosis, running mechanics, foot type (pes cavus or pes planus foot types), and muscle fatigue. None have been shown to be a definitive risk factor, but they are believed to often occur in combination. Excessive contraction of the ankle plantarflexors is thought to play a role in fibula stress fractures.

Presenting Signs and Symptoms

Athletes will typically present with progressively worsening pain in the shins with running. Typically with medial tibial stress syndrome, or "shin splints," athletes may have reduction of their pain with running. With stress fractures, the pain tends to get progressively worse with longer periods of impact, as in running or jumping. Often, there is a focal area of pain rather than a large, diffuse area, as is commonly observed in shin splints. The athlete may limp with activity and often will have pain most of the time with just walking. There may have been attempts at taking rest for several days to weeks, only to have the pain recur quickly with resumption of activity. A recent increase in activity or mileage may have occurred.

Physical Exam Findings

Often on exam, the athlete will have a focal area of tenderness to palpation where the stress fracture is located. Pitting edema may be present in the area of the stress fracture. A limp may be present. It has been reported that placing a vibrating tuning fork over the tender area will cause a significant increase in pain, aiding in the diagnosis. Attempting a single leg hop on the affected side often is positive for pain, and many athletes will not want to attempt this as they may have already experienced significant pain with a similar maneuver. Evaluation for foot pronation or supination should be done, but its usefulness may be limited as the athlete may be walking differently to avoid pain with walking.

Radiologic Findings

Initial evaluation should be done with plain-film X-rays. In the first few weeks of symptoms, it is not unusual to have normal X-rays. Many tibia stress fractures will not show up in radiographic images even after healing has begun. Fibula stress fractures will tend to give radiographic evidence of healing, evident by either a fracture line or callus formation, by 3 to 4 weeks after symptoms have started.

Early in the diagnostic process, it is often necessary to consider further imaging if the clinical suspicion is high for a stress fracture. Both bone scans and magnetic resonance imaging (MRI) scans are used, with MRI scans being slightly more sensitive and specific. MRI scans also have the advantage of being able to evaluate other adjacent structures besides the bone that may be causing pain, and there is no radiation involved. The MRI scan may also help distinguish between a stress reaction, where the bone has not progressed to failure of the cortical bone, and a true stress fracture.

Treatment

Essentially, all fibula stress fractures and the majority of tibia stress fractures are treated nonsurgically. Stress fractures of both the fibula and the tibia respond to rest from impact activity. Rest periods typically range from 4 to 6 weeks but may take up to 8 weeks. Athletes who are limping or having a difficult time with pain with general ambulation may need crutches, a pneumatic brace, or a walking boot for a few weeks to aid in the healing process and for pain relief. Avoidance of frequent use of anti-inflammatory medications is recommended due to the possibility of delayed healing that has been reported with the use of these medications for fractures.

Nonimpact cross-training, such as the use of an elliptical trainer, cycling, or swimming, should be recommended to maintain fitness. Once healing has occurred, gradual resumption of activity is recommended. Evaluation of footwear, running mechanics, and the potential need for over-the-counter or custom foot orthotics should be done to prevent recurrence.

Stress fractures of the anterior tibia frequently are treated surgically with an intramedullary nail. Nonoperative treatment may be undertaken, but it often takes 9 to 12 months for healing to occur.

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See also Lower Leg Injuries; Sports Injuries, Overuse; Stress Fractures

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Tibial Tubercle Avulsion Fracture

Avulsion of the tibial tubercle occurs when the traction on the patellar tendon exceeds the strength of the tibial tubercle. The majority of tibial tubercle avulsions occur in adolescents during jumping sports, particularly due to an eccentric load to the patellar tendon during landing. Tibial tuberosity fractures have been reported almost exclusively in males.

Anatomy

The patellofemoral joint is the articulation of the femur (thighbone) and the patella (kneecap). The patella is a sesamoid (floating) bone within a large thick tendon. Above the patella, this tendon is termed the *quadriceps tendon*, and the continuation below the patella is termed the *patellar tendon*. As the quadriceps muscle contracts, it pulls on the quadriceps and patellar tendon, causing the knee to straighten.

The patellar tendon inserts onto the tibia (shinbone) on the tibial tubercle. In the growing adolescent, the physis (growth plate) of the tibia is located just under the knee joint. Above the physis, there are two centers of ossification, the larger tibial epiphysis and the smaller tibial tubercle apophysis, although in older adolescents, they may coalesce to form a continuous epiphysis.

Causes

This is usually an acute injury caused by either violent contraction of the quadriceps muscle against a fixed tibia (as in jumping) or flexion of the knee against a contracted quadriceps.

Symptoms

There will be swelling and tenderness over the front of the tibia, just below the kneecap. Fluid may be present in the knee, and a triangular fragment of bone may be felt. The injured knee may be held in mild flexion, and there will be difficultly extending it.

Diagnosis

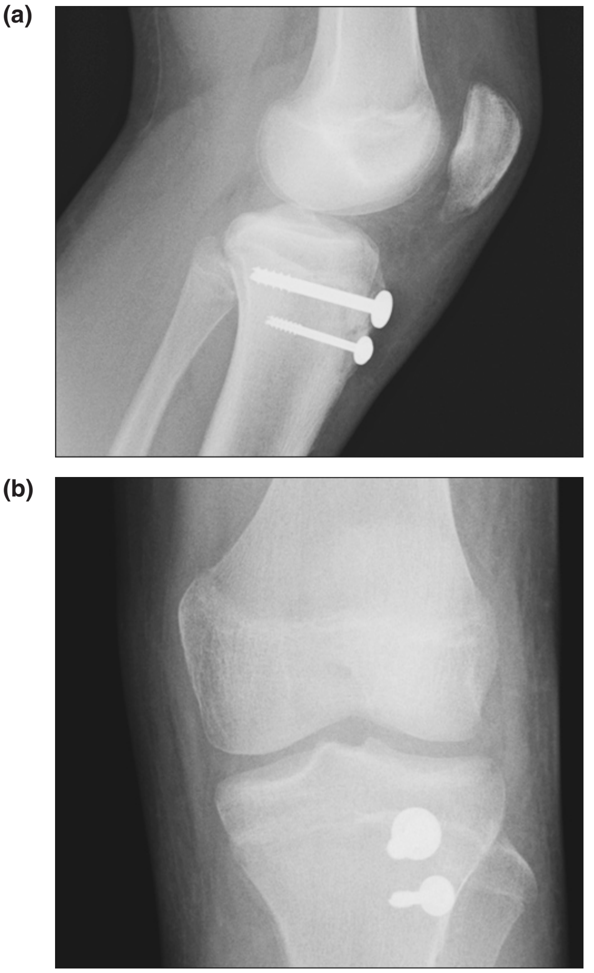
A complete physical exam is done to look for swelling and tenderness. The degree of patella alta (high-riding kneecap) will be proportional to the severity of the injury. The patient will be unable to fully extend the knee.

X-rays of the knee are mandatory, with the lateral projection being the most important (see X-ray below). The physician must be aware that in children and adolescents (ages 9 to 17), the normal tibial tubercle may not be fully ossified.

Several different classification systems, most commonly the Watson-Jones, are used for tibial tubercle avulsion fractures. In general, the most important point of difference is whether the fracture is nondisplaced or displaced.

Lateral view of a tibial tubercle fracture

Source: Yi-Meng Yen, M.D.



Tibial tubercle fracture after open reduction and internal fixation with two screws and washers; (a) lateral view and (b) anteroposterior view

Source: Yi-Meng Yen, M.D.

Treatment

Closed Reduction and Immobilization

In cases where there is minimal displacement of the tubercle, it is important to understand that the tibial tubercle is still being pulled by the force of the quadriceps into a displaced position. A closed reduction can be attempted and the knee casted. Even in a long leg cast, with the knee in full extension, there can still be tension on the tibial tubercle, so these fractures must be watched closely.

Surgery

Most specialists recommend open reduction and internal fixation of all displaced tibial tubercle fractures. This consists of making a vertical midline incision over the fracture site. The fracture is reduced (put back into place), and metal screws or pins are used to hold the fragment. The patellar tendon and other soft tissues may be sutured down as well to ensure that the screws or pins hold the fragment in place (see images a and b, left).

After Surgery

Depending on the quality of the fixation, patients are placed in either a brace that limits motion or a cast in extension. Crutches are used for touchdown weight bearing for a period of 5 to 6 weeks, at which time progressive full weight bearing can begin. Physical therapy is initiated to help the patient regain knee motion and strength. The patient is not allowed to resume impact activities until motion and strength are regained and the fracture has healed. This typically takes between 3 and 6 months.

Yi-Meng Yen

See also Avulsion Fractures; Tibia and Fibula Fractures; Young Athlete

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TITLE IX, EDUCATION AMENDMENTS OF 1972

Women's position within the world of sports has changed drastically over the past 40 years. This is in large part due to Title IX of the Education Amendments of 1972, legislation originally intended to provide women with improved access to higher education. Title IX states, "No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance."

Prior to this law, it was difficult to nearly impossible for a woman to pursue a career in any field other than nursing, education, social work, or library science. Females were also excluded from major sporting events. The first female to compete in an organized marathon was Kathrine Switzer, in 1967. She registered for the Boston Marathon as K. Switzer to hide her gender and avoid being denied participation. Title IX addressed this discrimination by including all federally funded programs within its purview, such as intramural sports, club sports, and varsity athletics. This new awareness of gender equity in sports led to the Amateur Sports Act of 1978. This act prohibits discrimination on the basis of gender, race, and physical disability in open, nonschool amateur sports. These would include Olympic, Pan American, world championship, and other international sporting events.

To further clarify the scope of this legislation, Title IX governs the overall equity of treatment and opportunity in athletics while giving schools the flexibility to choose sports based on the interests of the students, geographic influence, budget restraints, and gender ratio. In other words, it is a not a matter of women being allowed to participate in wrestling or that exactly the same amount of money is spent for a female as for a male basketball player. Instead, the focus is on the necessity for women to have equal opportunities with men on a collective, not on an individual, basis.

The impact of Title IX is far reaching. More females are participating in sports than ever before. In 1972, 1 in 27 high school girls played varsity sports. In 1988, this had improved to 1 in 3, whereas 1 in 2 boys participated in varsity high school sports. Women now view themselves as strong, competitive, and skilled athletes. In most circumstances, girls are encouraged by their parents at an early age to participate in sports. Parents have realized that the physical, psychological, and social well-being of their daughters is improved through sports participation. Adolescents who participate in sports are less than half as likely to get pregnant as those with more sedentary habits. They often have greater confidence, self-esteem, and pride; indulge less in high–health risk behaviors such as smoking, drinking, and illicit drug use; are more likely to achieve academic success; graduate from college at a significantly higher rate; and suffer less from depression than those who do not participate in sports. These benefits may be due, in part, to the added benefits of sports, such as teamwork, goal setting, the pursuit of excellence in performance, and other achievement-oriented behaviors necessary for success in the workplace. Parents also realize that the quality of life for their children will likely depend on two incomes. This necessitates the training of daughters as well as sons, and sports participation is an excellent vehicle. Women's participation in sports is now deeply entrenched in core family values, with families enthusiastically supporting the sports participation of both their daughters and their sons.

The academic impact has also been demonstrated. In 1994, women received 38% of medical degrees, compared with 9% in 1972; earned 43% of law degrees, compared with 7% in 1972; and 44% of all doctoral degrees received by U.S. citizens, up from 25% in 1977. These statistics support the previously noted benefits of sports, including higher college graduation rates and greater academic success.

Not only are women participating in larger numbers in a greater number of sports, but advertisers have found themselves a whole new world of focus—the female consumer. Women are buying sporting goods not only for themselves but also for their spouses and children. In fact, women make 80% of the household retail buying decisions. In addition, they buy disproportionately to their participation. For example, female golfers constitute only 20% of all golfers but buy 50% of all golf products with the exception of clubs. The economic power of the active female has led advertisers to focus more attention on the female athlete and sporting goods companies to produce high-quality equipment designed specifically with the female athlete in mind.

With few exceptions, female athletes are making good role models for young girls. The image of the female athlete is positive: nonviolent, appreciative, and hardworking. This is in stark contrast to the image of the professional male athlete, who is often viewed as selfish and arrogant. Although the influx of money and the popularity of women's sports may lead to negative behavior among some women athletes, this has not yet been the case. The general public embraces the spirit and effort with which females approach sports.

As of 2008, female participation in sports is the highest in history, at 9,101 intercollegiate teams and 8.65 women's teams per school. The most popular sport is basketball, followed by volleyball and soccer. In the past decade, 2,755 new women's teams have been created. This growth has been attributed to many factors, including mothers who have benefited from the Title IX legislation encouraging their daughters' sports participation, law suits supportive of Title IX, societal acceptance of females as athletes, improved and increased media coverage, and advocacy groups such as the National Association for Girls and Women in Sports and the National Association of Collegiate Women Athletic Administrators.

Women's sports participation has never been more encouraged and accessible than it is today. Women athletes now enjoy the support of their families, peers, and physicians. Every time a woman takes her place on the playing field, gets in the blocks for a race, or takes the court, she does so with a host of women who came before her paving the way for her to have the opportunity to participate, to be accepted as a viable athlete, and to further perpetuate a culture of athleticism for women. The full impact of a generation of women who are now maturing and who are growing up with opportunities that their mothers and grandmothers never dreamed of having remains to be seen.

Michelle Wilson and Jeffrey A. Guy

See also Benefits of Exercise and Sports; Female Athlete; History of Sports Medicine; Mental Health Benefits of Sports and Exercise

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Toenail Fungus

In the United States, an estimated 10 million individuals suffer from *onychomycosis,* a fungal infection of the nails. Although the exact incidence is not known, studies suggest that between 2% and 26% of the general population worldwide are affected. Onychomycosis is commonly seen in conjunction with tinea pedis or may occur secondary to trauma to the nail. Although both fingernails and toenails can be infected, onychomycosis occurs approximately four times more frequently in toenails than in fingernails.

A large survey done in Europe in 1997 through 1998 on patients presenting to general practitioners' offices clearly indicated that sports-active individuals have a higher incidence of tinea pedis and onychomycosis than do nonathletes people.

All athletes, regardless of age or type of sport, are at risk of developing onychomycosis. Fungi are known to thrive in moist, warm environments—conditions found inside an athlete's shoe or in the contact of bare feet with infected surfaces such as shower stalls, pool decks, and locker room floors. Trauma to the skin or nails from friction, rubbing, or maceration provides the portal of entry for fungi.

Athletes are also susceptible to toenail problems because of the speed and intensity of play (e.g., in running), the frequent starting and stopping in a game (e.g., in tennis and racquetball), and the type or absence of shoes (e.g., in ballet, gymnastics, or swimming).

Clinical Variants of Onychomycosis

There are four main types or clinical variants of onychomycosis:

1. *Distal subungual onychomycosis:* This infection starts at the hyponychium, the tip of the undersurface of the nail, and migrates proximally through the underlying nail matrix. This is usually caused by *Trichophyton rubrum.* This subtype is the most common (see the first photo).
2. *White superficial onychomycosis:* This variant accounts for 10% of onychomycosis cases. It is most commonly caused by *Trichophyton mentagrophytes* and invades the superficial layers of the nail plate, forming white islands.
3. *Proximal subungual onychomycosis:* This type is the least common in healthy people and usually occurs in immunocompromised patients. It is most commonly caused by *Trichophyton rubrum,* which invades the nail via the proximal nail fold and migrates distally.
4. *Candidal onychomycosis:* This type is seen in patients with chronic mucocutaneous candidiasis. The nail plate thickens and turns a yellow/brown color. This type generally involves all the fingernails.

Patient with distal subungual onychomycosis, the most common type of onychomycosis

Source: Peggy R. Cyr, M.D.

Differential Diagnosis

Not all thick, dystrophic toenails are caused by fungi. Fifty percent of thick nails are infected by fungi. The practitioner should perform diagnostic testing to determine if fungi are present. Psoriasis involving the nail is most commonly confused with onychomycosis, and the two diseases may coexist. Pitting of the nail plate surface is seen in psoriasis but not in onychomycosis. Eczema, lichen planus, or habitual picking of the proximal nail fold may induce dystrophic changes in the nail plate. Leukonychia are white spots or bands that are present in the proximal nail plate and grow out with the nail; they may be confused with onychomycosis.

Treatment

There are many options available today for treatment of onychomycosis. The athlete's medical history, concomitant illnesses, and medications must be reviewed carefully. Presenting the patient with published data on the effectiveness of each treatment, as well as the possible side effects, will lead to a joint decision on how to proceed.

Topical Agents

Ciclopirox nail lacquer 8% (Penlac) is approved by the Food and Drug Administration (FDA) for use in mild to moderate onychomycosis caused by *Trichophyton rubrum* with no lunula involvement. The medication is applied once daily to the nail, 5 millimeters of the surrounding skin, the nail bed, and the undersurface of the nail. A new coating is placed over the old one each day, and the medication is completely removed with rubbing alcohol once a week. Treatment extends up to 48 weeks, with periodic debridement of the infected nails. More aggressive debridement may increase the effectiveness of the medication. Published cure rates in the United States are 29% to 36%. In non-U.S. studies, the cure rates were higher; from 46.7% to 85.7%. This method will require a motivated patient to complete the treatment course. There are little to no side effects other than possible redness or irritation of the skin surrounding the nail.

Nail Avulsion Combined With Topical Treatment

This method should only be used for painful, severely affected nails as the procedure is temporarily disabling and painful. Complete toenail removal with phenol/alcohol nail bed ablation is considered in older athletes who have totally dystrophic toenails that are not growing or growing very slowly. Systemic antifungals are doomed to failure in this scenario since improvement depends on the dystrophic nail growing out and being replaced by a new nail proximally. After the procedure, activity must be limited until the nail bed heals. Then, for 6 to 12 months, a bandage must be worn over the freshly healed skin to prevent blistering. After that time, the skin would have developed enough anchoring fibrils, enabling the athlete to engage in any kind of athletic activity without limitation. Debridement of the part of the affected nail that is not attached to the nail bed is encouraged for all patients.

Oral Agents

Griseofulvin (Gris-peg) and ketoconazole (Nizoral) have been available for many years but are no longer considered first-line treatment due to the need for a prolonged treatment course (10–18 months), the low success rates, and the high rates of relapse. Studies show that 90% of patients who were clinically cured after prolonged griseofulvin therapy relapsed 1 to 2 years later.

The newer triazole and allylamine antifungals have replaced griseofulvin and ketoconazole in the treatment of onychomycosis. These drugs, terbinafine (Lamisil), itraconazole (Sporanox), and fluconazole (Diflucan), all promptly penetrate the nail and nail bed, persist for months in the nail after discontinuation of treatment, and have good safety profiles. Each agent has potential drug interactions as well as different dosing options. The FDA approves the use of all these agents, except fluconazole, in treating onychomycosis.

Terbinafine (Lamisil) is the preferred treatment for onychomycosis. Dosing options are 250 milligrams (mg)/day for 12 weeks for toenails and 6 weeks for fingernails. Cure rates are 71% to 82%. There are fewer interactions with this medication than with the other oral antifungals. Another dosing option is 250 mg/day for 1 week every month for 11 or more months until a new nail has grown. In one study, the cure rate was 90%. Headache, rash, and gastrointestinal upset are possible but infrequent side effects. Rare but serious complications include cholestatic hepatitis, blood dyscrasias, and Stevens-Johnson syndrome. It is prudent to take liver function tests and check complete blood count before treatment starts and every 6 weeks during continuous-treatment protocols. If liver functions rise greater than two times above the normal, the medication should be stopped.

Itraconazole (Sporanox) in doses of 200 mg/day for 12 weeks for toenails and 6 weeks for fingernails or pulse therapy at 400 mg/day in the first week of each month can be prescribed. Two to three pulses are recommended for fingernails and three to four pulses for toenails. Liver enzyme monitoring is recommended for continuous therapy but is not considered to be needed for pulse therapy. Published cure rates are 35% to 80%. Because itraconazole is metabolized by hepatic cytochrome P450, significant drug interactions can occur with anti-arrhythmics, HMG CO-A (3-hydroxy-3-methylglutaryl-coenzyme A) reductase inhibitors, benzodiazepines, histamine blockers, and proton pump inhibitors. These interactions make this drug less desirable.

Fluconazole (Diflucan) in doses of 150 mg once weekly for 6 to 9 months can be used. This medication is the treatment of choice for onychomycosis caused by *Candida* but is also effective against other dermatophytes. Published outcomes show clinical improvement in 72% to 89% of the cases. Significant drug interactions can occur with benzodiazepines, cimetidine, HCTZ (hydrochlorothiazide), hypoglycemics, rifampin, theophylline, and coumadin.

Prevention

Most cases of onychomycosis can be prevented by early recognition and treatment of tinea pedis. Any athlete with a rash on his or her feet should have a potassium hydroxide examination of skin scrapings. The rash of tinea pedis may be maceration in the web spaces of the toes, scaling with or without erythema along the lateral aspect of the sole, or inflammatory vesicles along the instep. Dry moccasin scaling is another variation on the appearance of tinea pedis. Tinea pedis can be treated with topical antifungal cream (Spectazole) and antifungal powder (Zeasorb AF). There are numerous over-the-counter antifungal preparations, such as clotrimazole (Lotrimin) and tolnaftate (Tinactin). A simple approach is to place antifungal powder in all shoes in one's closet every Sunday so that compliance is enhanced as different shoes are worn throughout the week. Compliance is the big issue when it comes to long-term prevention strategies. Resistant or severe cases may require oral antifungal agents.

Athletes should use cotton socks for wicking away moisture and wear sandals in locker rooms, pool decks, and shower stalls. Properly fitting shoes are important to prevent microtrauma to the nails. Daily laundering of socks is recommended.

Ciclopirox 8% applied to the nail and nail fold two to three times per week may prevent recurrence after successful treatment of onychomycosis.

Return to Sports

There are no specific return-to-play NCAA (National Collegiate Athletic Association) guidelines for onychomycosis. Wearing sandals in locker rooms and showers is important, particularly until an athlete has been successfully treated.

The toenails may be the starting place for developing tinea on the other parts of the body. Tinea corporis gladiatorum has been described in wrestlers. Though the toenails of wrestlers are covered by shoes, examination of wrestlers with onychomycosis will reveal that many have exposed patches of tinea. Clearing the toenails eliminates the reservoir for fungus in these athletes, decreases the opportunity for development of tinea on exposed surfaces, and therefore decreases the possibility of its spread to other athletes.

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See also Dermatology in Sports; Fungal Skin Infections and Parasitic Infestations; Podiatric Sports Medicine

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Torticollis, Acute

Acute torticollis, also known as *wryneck,* is a twisting of the neck causing the head to be tilted and rotated to one side. It is typically caused by spasms of the muscles on one side of the neck. Torticollis may be congenital (present at birth), but acute torticollis usually affects individuals between the ages of 30 and 60, with a greater incidence in females than in males. Athletes in any sport may develop torticollis for a variety of reasons. In contact sports, such as football or basketball, acute torticollis may develop from collisions to the head or torso, which strain the neck muscles. The effects of the collision may manifest immediately or even days later. In other sports, improper technique or overuse and repetitive motions, such as looking up during a tennis serve or shooting a rifle, place the neck in positions that may be prone to spasms.

Anatomy

The neck normally has seven vertebral bodies, which make up the cervical portion of the spine. A vertebral disk, which acts as a shock absorber for the neck and allows for smoother neck motion, separates each of the seven spinal segments. Attached to these segments are numerous ligaments, which provide stability, and muscles, which allow the neck to flex, extend, bend sideways, and rotate. The muscles that are primarily involved in acute torticollis, and can individually or collectively spasm, are the sternocleidomastoid, trapezius, occipitalis, splenius, and levator scapulae.

Causes

Acute torticollis involves irritation of the cervical nerves leading to abnormal neck contractions and is commonly, but not always, caused by some inciting incident, such as rapid head or neck movements or injury from whiplash or concussion. Often, individuals will develop acute torticollis from keeping their head and neck in awkward positions for prolonged periods of time (e.g., sleeping in a wrong position or on a new bed or pillow). If there is a history of forceful trauma to the neck, other etiologies to consider are fracture, dislocation/subluxation, slipped facets, or disk herniation. Medical causes that should not be overlooked and may have a similar presentation are bacterial or viral infections in the head or neck or underlying chronic inflammatory or neurologic diseases. Certain medications can also cause acute torticollis.

Symptoms

Acute torticollis typically presents 1 to 2 days following neck irritation, although symptoms may not develop for several weeks or months. It is usually painful in the neck muscles or down the spine, and the individual has difficulty turning the head to one side. The head may tilt in one direction as the chin tilts in the opposite direction. Involuntary head shaking may occur as a direct result of muscular spasm.

Diagnosis

Acute torticollis is diagnosed by a thorough medical history and physical examination. Special attention to recent or past neck injuries, acuity of onset, pain location and radiation, fevers, and medications can help in confirming the diagnosis. The presenting posture is the head bent sideways in one direction with the chin pointing in the opposite direction. Active range of motion of the neck is usually limited, and the examiner may be able to palpate spasm and elicit tenderness of the affected muscle. The physical examination should also include evaluation of the eyes, ears, nose, mouth, and pharynx. A complete neurologic examination, including the neck and upper extremity, should be performed, and if abnormalities are present, further workup is warranted.

X-rays of the cervical spine can be taken if there is a suspicion of fracture or subluxation. More advanced imaging studies, such as computed tomography (CT) or magnetic resonance imaging (MRI) scans, can be ordered if there is concern about infection (i.e., abscess) or deeper anatomic abnormalities (i.e., disk herniation). No specific laboratory studies are required for acute torticollis unless occult infection or chronic inflammatory conditions need to be ruled out. Electromyography (EMG) can be a useful tool to determine the degree of muscle or nerve involvement.

Treatment

Treatment for acute torticollis is primarily symptomatic. Frequently, the spasms will subside on their own after about a week. Noninvasive modalities include gentle passive stretching of the neck, massage, warm compresses, and a short course of wearing a soft cervical collar for comfort and to allow the muscles to relax. Medications that may provide some benefit include nonsteroidal anti-inflammatory drugs (NSAIDs) and benzodiazepines or other muscle relaxants. If symptoms are prolonged and continue for several weeks or months, botulinum toxin (Botox) injections can be administered, usually by a neurologist or other specialist. These injections help prevent involuntary muscle contractions.

Most of the time, acute torticollis improves with nonsurgical intervention. However, if the problem becomes chronic, selective denervation of the affected muscle (irreversibly severing the nerve supplying the contracted muscle) may be considered. Physical therapy involving manual stretching and strengthening and range-of-motion exercises are started after approximately 1 week.

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See also Neck and Upper Back Injuries; Neck Spasm; Sports Injuries, Overuse

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Transsexual Athletes

In all but a few sporting disciplines, Olympic competition follows the tradition of segregation of the sexes, which has been defended on the basis of the physiological differences that exist between adult males and females. Prior to puberty, there are no significant differences between the performance abilities of boys and girls. However, during puberty hormonal differences emerge that form the basis for the superior strength, power, and aerobic capacity that males possess, on average, compared with the average postpubertal female. Interestingly, however, as females have come to enjoy greater opportunities in sports, the performance gap between elite female and elite male athletes has become noticeably narrower. Nevertheless, it is still commonly accepted that it would be unfair to permit males to compete against females in the "gender-affected" sports (defined as those sports in which the physical strength, stamina, or physique of average persons of one sex would give them an advantage over average persons of the other sex).

In an effort to maintain the level playing field promised by sex segregation, for nearly three and a half decades, many sports governing bodies and the International Olympic Committee (IOC) pursued a program of "gender verification." The fear was that unscrupulous men might masquerade as women to compete against the "weaker sex," thereby unfairly gaining the laurels of victory. Although the stated goal of gender verification seemed reasonable—given the accepted system of sex segregation—in practice, such testing earned a rather inglorious reputation for inappropriateness and inaccuracy. After repeated public calls for its discontinuation, the IOC finally abandoned routine sex testing prior to the 2000 Sydney Games. Interestingly, since the present doping code demands inspection of the external genitalia at the time of urine collection, a mechanism remains in place for randomly assessing an athlete's phenotypic sex. Olympic medical regulations permit further medical intervention to determine an athlete's true sex should there be medical suspicion of improper participation.

In retrospect, gender verification failed in part because the methodology employed failed to accurately identify those genetic intersex states that confer a performance advantage. The phenotypic and genotypic combinations that are associated with the intersex states confound the commonly accepted definitions of what constitutes male and female and thus challenge the simple binary understanding of sex that society has accepted as normal. Similarly, transsexualism blurs the physiological borders between male and female in ways that challenge our accepted beliefs about sex. Indeed, the issue of how to integrate transsexual athletes into elite sports has proven to be quite contentious. The critical question is whether transsexual athletes (particularly postpubertal male-to-female [MTF] transsexual athletes) have an unfair performance advantage over other female athletes.

Transsexualism refers specifically to individuals who identify with (and wish to be accepted as a member of) the sex opposite to that assigned to them at birth. As such, it falls at one end of the transgender spectrum. Our current understanding suggests that transsexuals feel compelled to transition from their assigned birth sex to the opposite sex out of a prevailing sense that their true gender is at odds with their birth sex, a condition known as gender identity disorder. The resulting gender dysphoria is considered to be incurable, and the interventions to transform one's sex—which include exogenous administration of hormones and surgical sexual reassignment—are therefore merely palliative. Once transitioned from their assigned birth sex to their acquired sex, the transsexual's genotype and phenotype are disconnected, and it is only through ongoing manipulation of their hormonal milieu that transsexuals are able to maintain their acquired physiology.

Exogenous administration of sex hormones therefore represents the cornerstone of therapy for gender identity disorder and is the mechanism for effecting the desired physiologic cross-sex transition. Sexual reassignment surgery is available to those who wish to complete the phenotypic conversion. Studies of postpubertal MTF transsexuals have documented the effects of prolonged androgen suppression combined with estrogen supplementation, including significant decreases in total and regional muscle mass, muscle strength, and bone density and significant increases in total and regional fat mass. However, no peer-reviewed studies have been published describing the effects of long-term cross-sex hormone therapy on sports performance.

Consequently, it is unclear whether any significant physiologic performance advantage exists for the fully transitioned MTF transsexual athlete over an elite athlete who retains her female birth sex. Of course, those MTF transsexuals who transition after puberty will (at least partially) retain the acquired skeletal effects of testosterone exposure (e.g., height), which could prove advantageous in selected sports. However, given the wide-ranging physiological differences that exist between elite athletes, it seems likely that the abilities of the vast majority of transsexual athletes will fall within the existing spectrum of sex- and sport-specific athletic performance capacity. As a case in point, consider the pioneering MTF transsexual athlete Renée Richards. Although she achieved considerable success in tennis, her level of accomplishment did not outstrip prior levels of accomplishment attained by other athletes (who were presumably females at birth). Unfortunately, Richards was forced to overcome daunting obstacles (not the least of which was public scorn) in order to compete in her chosen sport.

The debate over whether transsexuals should be permitted to compete in sports as members of their acquired sex seemingly intensified when the IOC decided to critically examine the issue. After considerable deliberation, in 2004 the Committee voted to permit transsexual athletes who meet strict criteria to participate in the Olympics (see Table 1). The IOC's decision (the "Stockholm Consensus") led to an outcry of protest from those who feared that the existing competitive balance in elite women's sport would be upset by the influx of poorly feminized transsexuals. Despite these concerns, such a competitive imbalance has yet to materialize at the Olympic level, as no openly transsexual athletes competed in the Games of Athens, Torino, or Beijing. It is not known whether this reflects transsexual athletes' unwillingness to publicize their status or other factors (e.g., failure to qualify or simply the low number of elite transgender athletes).

It appears unlikely that the question of whether it is fair for postpubertal transsexual athletes to compete in sports against athletes who share their acquired sex will be resolved unless convincing new information is brought to bear on the matter. Of course, the difficulty in agreeing on what is fair lies in the fact that fairness is a subjective value. Even so, research should help inform the constituents whether consistent sport-specific performance advantages exist for the transsexual athlete, and education can help correct the misinformation and alleviate the prejudice that inevitably accompanies consideration of this issue. Meanwhile, in the United Kingdom, politicians have entered into the discussion. Shortly after the Stockholm Consensus was announced, Parliament revised its statutes concerning sex discrimination. The Gender Recognition Act (GRA) of 2004 provided transsexuals with the important legal right to be identified as belonging to their acquired gender. However, Section 19 of the GRA specifies that "in certain circumstances" transsexuals may be restricted

Table 1 Olympic Eligibility Criteria for Transsexual Athletes, Based on the Stockholm Consensus

Birth Sex	*Acquired Sex*	*Timing of Intervention*	*Duration of Therapy*	*Sex Reassignment Surgery Required?*	*Legal Recognition*
Male	Female	Prepubertal	Ongoing	Yes	Required
Female	Male	Prepubertal	Ongoing	Yes	Required
Male	Female	Postpubertal	2 years minimum	Yes	Required
Female	Male	Postpubertal	2 years minimum	Yes	Required

from competing in certain gender-affected sports to "ensure fair competition."

Apart from the ongoing debate, from a practical standpoint, the sports medicine practitioner who encounters a transsexual athlete should remember the unique aspects of transsexual physiology. Hormonal therapy is not without undesirable side effects, including (but not limited to) effects on cardiovascular health and hepatic function. Interestingly, however, one study of 293 female-to-male (FTM) transsexuals failed to demonstrate any significant increase in cardiovascular disease compared with the general population. The effect of hormonal manipulation on transsexual injury risk and recovery from injury remains largely unexplored. It is also critically important for all involved to remember that to be eligible to compete in the Olympic Games, the FTM athlete must obtain a Therapeutic Use Exemption (TUE) permitting exogenous administration of androgens. Failure to do so would constitute a doping violation. Of course, in light of the Stockholm Consensus, gender identity disorder is now an IOC-recognized diagnosis, and thus, FTM transsexuals should be eligible for a TUE providing they satisfy the strict IOC criteria governing transsexual participation.

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See also History of Sports Medicine; Performance Enhancement, Doping, Therapeutic Use Exemptions; World Anti-Doping Agency

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Travel Medicine and the International Athlete

Travel medicine is the discipline devoted to the maintenance of the health of international travelers through health promotion and disease prevention. It is a multidisciplinary field, encompassing a wide variety of specialties and subspecialties, including infectious and tropical diseases, public health and preventive medicine, primary care, and geographic, occupational, military, and wilderness medicine. Recently, travel medicine has broadened to include migration medicine, immigrant health, and a focus on the impact of travel on receiving countries. Unlike many other health care specialties, depending on the country, travel medicine is often practiced by both nurses and physicians.

The worldwide focus and knowledge base of travel medicine distinguishes it from most other fields of medicine and nursing. Travel medicine practitioners must be aware of infectious disease risks and their magnitude, patterns of drug resistance, current outbreaks of illness, civil and military conflicts, and political barriers to travel at border crossings. In addition, they must have access to the most up-to-date information on travel-related vaccines and medications.

Today, the focus of travel medicine is on recreational tourists, business persons, overseas volunteers, missionaries, and the military. In addition, the current era of the increasing popularity of ecotourism and extreme travel has added a new dimension to the field. Professionals counsel increasing numbers of immune-compromised individuals, such as those with HIV (human immunodeficiency virus) infection, cancer, autoimmune disease, or organ transplants.

Health Advice to Travelers

Health risks are increasing for travelers to developing countries. These can easily be overcome, however, through the dissemination of accurate information. Public health organizations have excelled in gathering information on the extent of disease prevalence and on prevention and treatment. They have made such knowledge readily available to hospitals, physicians, and the travel industry. The news media can do much to disseminate information in ways that enhance the enjoyment of travel to the developing world, instead of frightening people away.

Travel advice is based on the recommendations of the Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) and is supplemented by information provided by International SOS.

Before Traveling Out of a Country

Before traveling abroad, it is important to schedule an appointment with a health care provider at least 4 to 6 weeks in advance to discuss any needed vaccines or medications to prevent disease while traveling.

People with medical problems such as arrhythmias, clotting disorders, lung problems, or heart failure should discuss travel plans with their doctor even sooner. Even within small countries, diseases such as malaria might be a risk in one city but not in another, so it makes a difference to know exactly where a person will be going and what he or she will be doing. Also, the person must bring along a copy of previous immunizations. For the traveler's own safety, it is necessary, for all travel, that he or she is up-to-date on routine vaccinations. Most doctors also recommend hepatitis A and B vaccines for travelers. Based on travel plans, the doctor will then make recommendations about taking drugs to prevent malaria or vaccines to prevent yellow fever, typhoid, and other infectious diseases.

There are very few actual required vaccinations for travel, but this again depends on where the traveler will be going and when. The physician may refer the person to a travel medicine clinic if certain vaccinations are needed that are not readily available in regular clinics.

Those with underlying health problems should, with appropriate pretravel planning and behavioral modification during travel, be able to minimize the health risks associated with the travel. However, they must have realistic expectations concerning health maintenance and travel restrictions. Those individuals at special risk have the option of making use of numerous resources that are now available to make travel an enjoyable and rewarding experience.

Travelers to developing countries, particularly those visiting friends and relatives, have the highest morbidity for infectious diseases, including typhoid, hepatitis A, malaria, tuberculosis, and HIV infection. This is associated with their lifestyle, behavior, culture, and beliefs. Improvements in travel medicine practice, including the development of new antimalarial drugs and novel vaccines, have been of little benefit to this group of travelers, as can be seen from the increasing trend of morbidity. Pretravel services are underused by this population, and there is little material adapted to the language and cultures of developing countries. A major shift in practice will be necessary to benefit these vulnerable travelers.

Preventing infection among business travelers is one of the key areas of the travel consultation. Prevention methods include timely vaccination, hygienic food and water, precautions against insects, and tuberculosis screening.

The business traveler, corporation, and medical practitioner have mutual responsibilities to ensure the health and safety of the traveler and consequently the success of the trip. The most effective way to manage this responsibility is through the use of medical practitioners with an expertise in both occupational and travel medicine. An effective travel consult should identify means for the prevention of disease and provide the appropriate anticipatory guidance to the individual who is travelling. In addition, the travel consultant should also address the potential health and safety liabilities to the company when clearing personnel for business-related travel. The corporate traveler and employer must have an effective plan for medical emergencies prior to the traveler's departure. On their return, long-term corporate travelers should have reentry physicals and health debriefings. Finally, to maximize preventive efforts, particularly in relation to future travel, business travelers should complete the vaccination series that were begun prior to travel.

Medical Support for Travelling Athletes

Professional and amateur sports require frequent travel. Athletes are confronted frequently with obstacles to optimal performance. The trainers, medical team, and staff face challenges in providing support while traveling and working.

Physical examinations should include screening, the review of past medical history and vaccinations, and physical and dental examination. This will help establish the team member's preparedness to face the challenges of international travel. This examination could identify medical problems such as travel anxiety, asthma, dental caries, gastrointestinal problems, allergies, diabetes mellitus, and coronary heart disease. All medical records of the athletes should be kept secure and accessible in the hand luggage during travel.

Large athletic events are frequently associated with outbreaks of infectious disease. All athletes and members of the team should have an up-to-date immunization status (i.e., measles, tetanus, diphtheria, polio, pertussis, rubella, and mumps). Medical team members and full-contact athletes (i.e., boxers, martial artists, and wrestlers) should have three doses of hepatitis B shots. Athletes traveling to developing countries should consider a hepatitis A vaccination. Athletes without any previous exposure to chickenpox should be vaccinated for varicella with two doses 4 to 8 weeks apart. Meningococcal and influenza vaccine should be considered. Vaccines against diseases such as rabies, typhoid, yellow fever, malaria, cholera, and Japanese encephalitis are recommended according to the guidelines of international agencies.

Education on preventing infectious disease during international competitions should be provided to athletes, coaches, and the staff accompanying the team. Recommended methods to prevent communicable disease during traveling are drinking bottled or purified water, hand washing with soap and water or using alcohol-based hand gel, washing or peeling fruits and vegetables before eating, eating fully cooked foods, and abstinence or use of condoms to avoid sexually transmitted infections.

The following measures should be taken to ensure preparedness for international travel. First, it should be assumed that nothing will be provided, regardless of the preparatory phase. Second, the teams should be self-sufficient. Third, communication with the host country is advisable beforehand (e.g., regarding electricity, water, telephones, the Internet, ice, examination tables, or towels). A travel health kit (first-aid items and antiseptic hand gel, antidiarrheal medication, thermometer) should be made available to athletes at all times. Medical health records of all athletes should be available. Weather forecasts should be reviewed before departure, and athletes traveling to high altitudes should have undergone acclimatization.

Problems arising during travel might relate to major time zone changes, modes of transportation, changes in climate and humidity, sun exposure, and differences in food, housing, language, and religion. Endemic infections such as hepatitis B, yellow fever, and typhoid may require clarification and appropriate immunization prior to travel. Immunization might require several months of preplanning to ensure adequate sero-conversion. Chemoprophylaxis for some diseases, such as malaria, should be initiated in advance.

Hygienic standards should be maintained during food preparation while traveling. At international competitions such as the Olympic Games, a diverse selection of food is available. This enables athletes and staff from around the world to have their normal diet.

Toxigenic *Escherichia coli* is a well-known agent responsible for "traveler's diarrhea." It can be communicated by contaminated water, so in case of any doubt about the safety of the water supply, the team should drink and brush their teeth only with bottled mineral water. Travel to a hot and humid environment warrants an adequate intake of fluid to prevent dehydration and hyperthermia. Sufficient consumption of fluids will change urine to a light color. This is a better indicator than thirst. Another monitoring method for dehydration is daily weight charting. Additional salt in the food or fluid is recommended.

It is important to plan air travel well to minimize the effects of traveling. Jet lag is due to the physiological changes that occur when the sleep-wake cycle is disrupted. Changes in hormone metabolism and body temperatures occur, which lead to feelings of confusion and exhaustion. Athletes should consider avoiding heavy training on arrival and instead participate in one or two light training sessions to ease their transition. It can take several days before these factors settle back into rhythm and maintain an appropriate balance. For every hour of time zone change, one day of accommodation may be required to overcome the effects of jet lag.

To minimize the effects of jet lag, athletes may try to adjust their sleep pattern over several days prior to departure to coincide with the time zone at the site of the competition. On the airplane flight, it helps to move around as much as possible, to avoid alcohol and coffee, and to ingest large amounts of fluid. It is recommended that athletes stay up on the day of arrival and try to adjust to the normal sleep pattern of the country in which they have arrived. Exercise after a long flight may prevent the malaise of jet lag. The use of high-protein meals and stimulating drugs such as caffeine, contained in beverages such as coffee and tea, may be temporarily useful for improving alertness at the time of arrival. Benzodiazepines could promote sleep during a long flight. Drowsiness and decrease of psychomotor performance are the side effects, which might decrease athletic performance. Therefore, these drugs should be reserved for traveling athletes with persistent insomnia, and their use should be supervised by a physician. Melatonin, a hormone that is secreted at night and plays a key role in circadian rhythms, is available as a drug. Conflicting evidence exists on the effects of melatonin on athletic performance and the amelioration of jet lag symptoms. Drowsiness and headaches might hinder sports performance if taken inappropriately. Athletes should use melatonin during flights if they are accustomed to the effects of this remedy. Long-distance travel should be interrupted for 1 to 2 days for a more gradual introduction to major time zone changes.

Motion sickness is another problem frequently encountered during traveling. Unstable air, mountainous roads, and heavy seas may trigger symptoms including nausea, vomiting, dizziness, headache, and malaise. Drugs such as dimenhydrinate, transdermal scopolamine, and meclizine when taken before travel may prevent symptoms of motion sickness.

Before setting off on the journey home, the same precautions for travel should be discussed with the team and athletes. Athletes with a medical problem or injury should be monitored closely, and preparations for their care at home should be made in advance. In case of a medical event, the team physician should prepare a health report on medical encounters, the type of injury or illness, treatments, and emergencies. The report may be presented to the local organizing committee and to the sports organizations back home. This approach will help explain the need for the medical services used and assist in preparations for future international athletic events.

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See also Blood-Borne Infections; HIV and the Athlete; Infectious Diseases in Sports Medicine; Team Physician

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Triangular Fibrocartilage Complex

The *triangular fibrocartilage complex* (TFCC) is a structure found in the wrist. The TFCC serves as the primary stabilizer of the distal wrist joint, as well as provides for cushioning from certain activities. It works in a similar fashion to the menisci found in the knee and is often called the "wrist meniscus." It can be injured either acutely during trauma or from repetitive overuse. There is some evidence that, over time, the TFCCs of all patients will begin to break down (usually beginning in the fourth decade of life) to a certain degree.

The TFCC is made up of several different structures. The primary components are the dorsal and palmar volar ligaments. These ligaments run from the radius to the ulna and provide for the structure of the TFCC. There is also a soft tissue disk that lies between these ligaments and provides extra support. Finally, a portion of the tendon sheath of the extensor carpi ulnaris (ECU) makes up a portion of the TFCC.

The TFCC can be injured either traumatically or through repetitive activity. Patients can suffer TFCC tears related to falls on their wrists and arms or from direct trauma to the ulnar side of the wrist. In particular, any trauma that results in the hand being forced downward against the ulna may result in a TFCC injury. TFCC injury from repetitive trauma and overuse is often seen in patients who perform activities that result in repetitive ulnar deviation of the wrist (e.g., lifting heavy weights, working with equipment such as hammers or drills). In addition, sports that result in repetitive compression of the wrist may result in TFCC tears; these sports include racquet sports, gymnastics, and diving. In addition, distal radius and ulnar fractures are often associated with TFCC tears.

The differential diagnosis of a TFCC tear includes, but is not limited to, fractures of the radius and/or ulna, tendinosis and tenosynovitis of the flexor or extensor tendons, displacement/snapping of the ECU tendon, injuries to other ligamentous or cartilaginous structures of the wrist (distal radioulnar joint [DRUJ], scapholunate, etc.), and arthroses of the wrist joint.

Diagnosis of a TFCC tear can be performed both clinically and radiographically. Typically, the patient will experience discomfort of varying degrees with palpation of the structure. Patients with small tears may experience little to no pain or limitations, while patients with larger and/or chronic tears may have constant debilitating pain both at rest and with use. The location of the tear will be important as well. Typically, the more peripheral a tear, the more likely it is to cause the patient discomfort; central tears of the TFCC can often be asymptomatic.

The outermost structure of the TFCC is easily palpated along the lateral wrist between the ulna and the lateral carpal bones (pisiform and hamate). Palpation of the structure can be accentuated with radial deviation of the hand. There may also be associated swelling around the structure, as well as "clicking" of the wrist, which may be heard or felt by the patient. Patients may also experience decreased grip strength and pain with resisted wrist dorsiflexion. The Apley Grind is the most commonly used diagnostic test. This test is usually performed with the physician gripping the hand of the patient and applying downward pressure, causing the hand to deviate toward the ulna. The hand can then have a twisting force applied to it, causing the TFCC to be compressed and exacerbating the pain.

Radiographic studies can also be of benefit in diagnosing TFCC injuries. Although the TFCC is a cartilaginous structure, X-rays can sometimes be helpful, for several reasons. With both trauma to the wrist and chronic pain, plain radiographs are often ordered to evaluate for bony injury. Evidence of an ulnar fracture of any form could alert the clinician to the possibility of a TFCC injury. More important, the shape of the ulna can help in making the diagnosis. In general, the lengths of the ulna and radius in the wrist are the same. However, in some patients, the ulna may be either longer or shorter than the radius; this is defined as positive or negative ulnar variance, respectively. Both positive and negative ulnar variance can be associated with a higher rate of TFCC injury.

To truly evaluate the TFCC, magnetic resonance imaging (MRI) is often required. This test allows visualization of the soft tissue of the wrist. This will often reveal swelling along the cartilage and sometimes a tear in the cartilage. The test can be made more accurate by the injection of contrast medium into the wrist. This procedure is called an *MR arthrogram*, and it can allow for better visualization of a TFCC tear, as the contrast material may actually track through the tear into other areas of the wrist where it was not injected. Computed tomographic (CT) arthrography may also be done, although it is typically not as accurate as MR arthrograms. Finally, the TFCC tear may be directly visualized through an arthroscopic procedure.

Treatment of TFCC tears can be both conservative and surgical. In general, nonoperative therapies are attempted first. Modalities such as protection from further injury, rest, and ice application are often helpful. Bracing is often used for mild and/or acute injuries as mild trauma to the TFCC may heal on its own. Bracing can be used with activities that cause pain and discomfort for the patient. At times, a cast can be used for a period of 2 to 4 weeks as well. This allows for immobilization as well as protection. This can be particularly helpful in cases of chronic TFCC injuries. Another option for treatment can be corticosteroid injection in or around the TFCC. This can be done for both diagnostic and therapeutic reasons. Also, both physical therapy and physiotherapy may be helpful. Finally, in cases that are resistant to conservative therapy, surgery can be an option. This surgery is usually accomplished arthroscopically and can be done for either acute or chronic tears. This intervention may result in either repair of the tear or excision of the fragments. Patients suffering from severe tears may be more likely to require surgical intervention. Also, if there are concomitant injuries to other structures of the wrist that require surgical intervention, then patients may undergo surgical correction of their TFCC injury at the same time.

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See also Triangular Fibrocartilage Injuries; Wrist Injuries; Young Athlete

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Triangular Fibrocartilage Injuries

The *triangular fibrocartilage complex* (TFCC) is a complex ligament-cartilage complex that sits between the distal ulna and the ulnar carpus. It serves as the main stabilizer of the distal radioulnar joint (DRUJ) and plays an important role in load bearing across the ulnar wrist. Tears of the TFCC are an important cause of both acute and chronic ulnar-sided wrist pain. This entry reviews the anatomy of the TFCC and discusses the classification, evaluation, and treatment of TFCC tears.

Anatomy/Function

The TFCC was first described by A. K. Palmer and F. W. Werner in 1981 and consists of an articular disk, a meniscus homologue, ulnocarpal ligament, dorsal and volar radioulnar ligament, and the extensor carpi ulnaris (ECU) sheath. It originates from the ulnar fossa of the distal radius and inserts into the base of the ulnar styloid. It is 2 millimeters (mm) thick on the radial side and 5 mm thick on the ulnar side. Distally, it inserts onto the lunate via the ulnolunate ligament (UL) and the triquetrum via the ulnotriquetral ligament (UT). The UL and UT ligaments are located volarly and are referred to as the disk carpal ligaments.

Blood supply is via the dorsal and palmar radiocarpal branches of the ulnar artery and the dorsal and palmar branches of the anterior interosseous artery. These vessels penetrate 10% to 40% of the periphery, leaving the central disk and radial portion avascular. As in the knee meniscus, peripheral tears are amenable to repair, whereas the central avascular portion does not heal.

As stated earlier, the primary function of the TFCC is as a stabilizer of the DRUJ. The volar portion of the TFCC prevents dorsal displacement of the ulna, and the dorsal portion prevents volar displacement of the ulna. Stability is achieved through selective tightening of the dorsal and volar TFCC during pronation and supination. The TFCC also increases the gliding surface for the radius and acts as a buttress to the proximal carpal row.

Another major function is to cushion axial loading through the ulnocarpal axis. The majority (80%) of axial load is carried by the radius; however, this can vary based on ulnar variance. Ulnar variance is a measure of the relative length of the ulna in relation to the radius. Studies have shown that a positive ulnar variance of 2.5 mm can increase load transmission by the TFCC to 42% while a negative ulnar variance of 2.5 mm can decrease load transmission to 4%. The increased load across the TFCC that occurs with positive ulnar variance accounts for its increased association with TFCC tears.

Examination/Evaluation

The most common symptom of a TFCC tear is ulnar-sided wrist pain with grinding or clicking during wrist range of motion. The mechanism of injury may be an acute fall onto an outstretched hand; a rotational injury with forced ulnar deviation, such as batting a baseball; or axial loading, such as in gymnastics. Chronic injuries result from overuse with repetitive rotation and loading of the ulnar wrist, also common in gymnasts. Isolated pain with pronation and supination may indicate injury to the articular disk, while constant pain with limited range of motion is associated with more peripheral tear.

Examination should include inspection for gross deformity, soft tissue swelling, erythema, and ecchymosis. Active and passive range of motion should include flexion, extension, pronation, supination, and radial and ulnar deviation. Patients are usually tender distal to the ulnar styloid in the soft depression just proximal to the pisiform. A painful click may be reproduced with repetitive pronation and supination of a clenched and ulnarly deviated wrist. Pain and/or clicking with the TFCC compression test may indicate a TFCC tear. This test involves wrist extension, ulnar deviation, and axial compression. DRUJ instability may be present, as evidenced by a positive "piano key sign," in which there is increased displacement of the distal ulna as the radius is held stable and the examiner forces or "shucks" the ulna in the volar and dorsal direction. The ulna appears more prominent and ballottable, resembling a piano key.

Plain radiographs are a useful initial imaging modality for TFCC injuries because they may reveal a distal radius or ulnar styloid fracture and also allow for assessment of ulnar variance. The recommended views are zero-rotation PA (posteroanterior) and lateral. Triple-injection arthrography used to be the study of choice but has been shown to have poor correlation with arthroscopic findings and has fallen out of favor over the past 5 to 10 years. The utility of magnetic resonance imaging (MRI) is debatable, with sensitivity ranging from 17% to 100% in conflicting studies. A dedicated wrist coil can improve accuracy, but MRI is still not ideal for localizing tears. The gold standard is wrist arthroscopy, which can be used diagnostically and therapeutically.

Differential Diagnosis

Examination should also be centered on excluding other common causes of ulnar-sided wrist pain. Dorsal pain may be caused by tendinitis or subluxation of the ECU. Patients with ECU tendinitis will have pain with resisted wrist extension and ulnar deviation. Subluxation may be present with a palpable, painful snap when a flexed, ulnarly deviated wrist is supinated. Lunotriquetral (LT) instability should be evaluated for with ballottement and shuck tests of the LT joint. Volar pain may be caused by flexor carpi ulnaris (FCU) tendinitis or a fracture of the hook of the hamate or pisiform. FCU tendinitis will present with pain with resisted wrist flexion and ulnar deviation. Hook of the hamate fractures present with hypothenar pain and are often caused by direct trauma to the hypothenar region from grasping an object, such as the butt of a golf club.

Classification of TFCC Tears

In 1989, A. K. Palmer devised a classification system for TFCC tears, distinguishing acute tears from chronic tears and helping guide treatment strategies. Class I tears are acute, traumatic tears. They are further divided based on the location of the tear. Type IA tears are of the central, avascular portion of the articular disk. Type IB tears occur at the base of the ulnar styloid with or without a distal ulnar fracture. Type IC tears are of the ulnolunate or ulnotriquetral ligament at the carpal attachment. Type ID tears are radial sided with or without a sigmoid notch fracture.

Type II tears are chronic and degenerative in nature, describing a spectrum of damage by repetitive loading and positive ulnar variance called ulnocarpal abutment syndrome. Types IIA and IIB tears do not have frank perforation but thinning of the disk without and with chondromalacia of the lunate or ulna, respectively. Type IIC tears are frank perforations of the central disk with chondromalacia. Type IID tears are frank perforations of the disk with chondromalacia and a tear of the LT ligament. Type IIE tears describe end-stage disease with perforation, chondromalacia, LT tear, and ulnocarpal arthritis.

Treatment

The initial treatment for both acute and symptomatic chronic tears is a period of immobilization in a long arm cast for 4 to 6 weeks followed by physical therapy. A localized cortisone injection may provide some symptomatic relief as well. Acute, peripheral tears (Types IB and IC) that are not associated with positive ulnar variance do very well with nonoperative treatment. In contrast, acute avascular tears (Types IA and ID) and both acute and chronic tears associated with ulnar impaction do not heal well without surgical debridement and ulnar-shortening procedures. The emphasis should be on correcting positive ulnar variance as many studies have shown poor outcomes for simple TFCC debridement without ulnar shortening. Types IIA and IIB lesions may only require ulnar shortening without arthroscopic debridement as they do not have frank tears. Type IIC tears may be treated with a “wafer” procedure, in which a 2- to 4-mm section on the distal ulna is removed while keeping the styloid, TFCC, and ligaments attached. Type IID tears with LT instability require ulnar shortening along with LT ligament repair or possible LT fusion or pinning. Type IIE lesions require a salvage procedure.

The TFCC is a complex structure that stabilizes the DRUJ and supports axial load across the ulnar wrist. TFCC tears represent an important cause of ulnar-sided wrist pain. Injuries are often caused by acute falls on an outstretched hand or chronic overloading of the ulnar wrist. The most common symptom is pain with clicking during wrist motion, and examination will often reveal pain with a TFCC compression test. TFCC tears are associated with positive ulnar variance, which can be seen on plain radiographs. Tears are classified as acute and degenerative, and treatment for both types is a period of immobilization followed by therapy. Arthroscopy is indicated for unstable lesions and those refractory to nonoperative treatment. Ulnar shortening should be performed for those with ulnar impaction syndrome.

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See also Sports Injuries, Acute; Triangular Fibrocartilage Complex; Wrist Injuries

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Triathlons, Injuries in

In the late 1970s, several endurance junkies started a contest to see who was tougher by swimming, biking, and running across the Hawaiian landscape. Over the decades that followed, the sport of triathlon has undergone a stunning rise in popularity. The individual medley of endurance sports (swim, bike, run) is now a well-accepted sport in the Olympics at the 1.5/40/10-kilometer distance and enjoys a wide and growing participation base across the world. Distances range from short, “sprint” races lasting less than 1 hour to longer-distance, “ironman” races that can take competitors up to 8 to 16 hours to complete. Some even extend this to ultradistances competed over several days. Races typically use road bicycles for the bike portion, but off-road races using mountain bicycles have been gaining in popularity as well. The medical and musculoskeletal issues that arise in the longitudinal care of triathletes are, for the most part, those that arise with training for each individual discipline. For those medical or other support personnel involved in race day coverage, however, a variety of other acute medical concerns may arise and need to be considered when planning for the medical coverage of such events.

Swimming

While competitive swimming involves training and racing using the four traditional strokes (butterfly stroke, backstroke, breaststroke, and freestyle) in an enclosed pool with clear, chlorinated water, a triathlon swim occurs in open water with variable conditions and with a multitude of other athletes. Mass start races are characterized by "pack" swimming, and this can occasionally lead to issues such as blunt trauma to the face/eyes and finger sprains from contact with other swimmers. Both hypothermia and hyperthermia have been seen during and after open-water swims. Triathletes will typically use wetsuits to combat the cooler water temperatures, and this will allow most athletes to tolerate long swims in temperatures as low as 10 °C (50 °F). Despite this, hypothermia can ensue both during the swim and after the swimmers exit the water, due to a phenomenon known as "after-drop." An athlete's core temperature can continue to drop after leaving the cold water as blood continues to perfuse the cooler extremities. This has led to injuries as athletes attempt to transition to the bike with impaired coordination and judgment as a result of hypothermia.

On the other end, the use of wetsuits in water greater than 25 °C (78 °F) can lead to elevations in core temperature and symptomatic hyperthermia (heat exhaustion, syncope, or heat stroke), and for this reason, wetsuit use is restricted above this temperature. Increases in core temperature and heat stress can be additive (from day to day and from event to event) and may progress during a race. Further elevations in core temperature accumulated during the bike and run segments could predispose an athlete to more symptomatic heat illness or exercise-associated collapse later. Heat exhaustion may present with confusion, weakness, cramping, or hypotension and may lead athletes to drop out of the race and present to the medical tent on their own. Heat stroke represents a progression of heat illness with system failure at the metabolic and organ levels. This is usually seen in the later stages of the run segment, with the athlete's collapse or severe deterioration in the medical tent.

To those athletes accustomed to training in clear water with orderly passing, the chaos of group swims and the unpredictable water conditions (cold temperature, waves, currents) can lead to anxiety and panic attacks. This problem can be exacerbated when warmer water conditions preclude wetsuit use. Many of the weaker swimmers depend on the additional flotation provided by wetsuit use, and a last-minute prohibition of its use can cause significant anxiety. Severe panic attacks in open water raise concerns about near-drowning events or severe exacerbation of asthma in the triathletes, and these should be accounted for when planning race management. Other, less common medical concerns during open-water swims include bacterial infections from poor water quality (*Escherichia coli, Leptospirosis*), sudden death from cardiac embolism or fatal arrhythmias, and marine animal stings or attacks (e.g., jellyfish, coral, sharks).

Triathletes, however, still need to put in a significant amount of distance in the pool during training (albeit less than their competitive swimmer counterparts due to the bike and run training) and thus experience the same range of overuse injuries as swimmers do. The shoulder is, by far, the most commonly injured or painful area in swimmers. Shoulder stability is maintained by both the joint capsule and the rotator cuff and can be lost when either of the structures becomes weakened. The rotator cuff is a group of four muscles deep inside the shoulder that helps provide stability by holding the humeral head inside its socket. It also helps initiate the overhead motion of the arm up to shoulder level. To achieve full overhead motion, the scapula must also retract and tilt the shoulder socket upward. The muscles that accomplish this are the rhomboids, trapezius, and cervical paraspinals.

The tendons of the rotator cuff are prone to overuse and inflammation with the repetitive overhead motion of the swim stoke. When this happens, the tired or inflamed muscle-tendon unit becomes weaker. As this progresses, the cuff muscles no longer constrain the shoulder effectively, and the head of the humerus may elevate with arm motion, causing a painful impingement against the undersurface of the acromioclavicular (AC) joint. Load may also shift to the joint capsule and ligaments, as well as the labrum (the cartilage rim around the shoulder joint). Such an imbalance can lead to painful multidirectional instability or labral tears. The scapular muscles must increase their share of moving the shoulder when the cuff is weak, and this can eventually cause overuse and lead to neck and upper back pain. The importance of a strong rotator cuff as a shoulder stabilizer becomes even greater in those with a high level of flexibility (congenital or otherwise) as these athletes cannot depend on the stabilizing effect of the shoulder capsule and ligaments.

Swimmers also experience injuries to various other structures. The repetitive lumber spine extension and rotation forces during a swim stroke can lead to stress injuries to the posterior elements of the vertebra itself and, ultimately, to spondylosis or spondylolisthesis. Injuries to the knee, such as patellofemoral pain or chondromalacia, can also be seen. These are usually seen with greater use of breaststroke or eggbeater kick, but can also be seen in those athletes concurrently training for bicycling, such as triathletes.

Cycling

Cycling injuries range from acute trauma to chronic overuse injuries. Triathletes, like cyclists, put in a lot of miles on the bike during the training process, and the old adage that "it is not *if* you will crash but *when*" holds true for triathletes. The most common crash-related injury is "road rash," which is a traumatic abrasion or contusion caused by the body scraping against the pavement. Appropriately treated with good wound care, it heals and rarely causes a significant loss of training time. Fractures of the wrist (distal radius, scaphoid), clavicle and AC joint, and elbow (radial head) are relatively common, and fractures of the pelvis have also been reported. The speed of a crash can increase the severity of a fracture; however, it is the mechanism of impact with the ground that determines whether a fracture will occur. Off-road triathlons have the added risk of collision with a fixed obstacle or even penetrating trauma from tree roots. Head injuries such as concussion also can result when a rider strikes the ground, even if he or she is wearing a helmet. Helmets are mandatory during competition and should be used during training as well.

Nontraumatic injuries, however, dominate in terms of frequency of cycling injuries. Chronic neck pain is a frequent complaint and can result from the prolonged neck extension required for straight-ahead vision with normal positioning on standard handlebars. This can be exacerbated by the increased torso flexion/flat-back positioning required with aerodynamic time-trial bars. The pain can be due to muscle spasm and/or trigger points in the levator scapulae, trapezius, or cervical paraspinal muscles, as well as from cervical facet arthrosis or degenerative cervical disk disease. To some degree, this can be minimized with more upright positioning on the bike.

The use of the hands and wrist to support the upper body on the handlebars can lead to both ulnar nerve impingement in the Guyon canal laterally in the wrist as well as median nerve irritation in the carpal tunnel. Consistent use of padded cycling gloves helps reduce trauma to the ulnar nerve. Frequent hand position changes and avoidance of extremes of flexion or extension help combat median nerve irritation. Groin injuries are also quite common in cyclists. Chronic irritation of the perineal skin due to friction can lead to skin breakdown and subsequent abscess formation. This can be minimized with proper bike positioning, padded cycling shorts, and chamois cream to soften the pad. Compression of the pudendal nerve can also cause transient numbness in the genital area. Such compression is more common in triathletes who tend to ride on the nose of the bike saddle.

Knee problems are also quite common in cyclists and triathletes. The pedal stroke can put tremendous load on the patellofemoral articulation, and proper pedaling mechanics and bike positioning are imperative to avoid overloading the joint. Even with good form, an overly rapid progression of high-power/low-cadence pedaling too early in the season can overwhelm the quadriceps muscle's ability to maintain normal patellar tracking. Inflammation of the patellar joint surface (patellofemoral pain) or softening/erosion of patellar cartilage (patellar chondromalacia) can occur. Once established, patellofemoral pain can take months to resolve. Chronic quadriceps muscle tightness can add to the problem by increasing baseline compressive stress on the joint. Similar cartilage erosions can occur on the femoral side of the joint as well. Chronic stress and overuse can also cause a painful intrasubstance degenerative change (tendinosis) within the patellar or quadriceps tendon. The same degenerative changes and inflammation that occur in the tendons of the knee also can occur in the Achilles tendon of the ankle with overuse. The iliotibial (IT) band attachment on the outside of the knee is also frequently injured with repetitive knee bending and friction at its attachment site.

Running

Run training can cause similar problems with knee pain. Patellar and/or femoral chondromalacia, IT band syndrome, and patellar/quadriceps tendinosis are all common overuse injuries in runners with normal mechanics. Those with poor mechanics that result in knee valgus (knock-knees), however, can experience increased patellar maltracking and pain. Such mechanical issues include abnormal foot pronation and weak core and/or gluteal muscles. Rapid increases in mileage, a large amount of downhill running, and uneven running surfaces all can increase the likelihood of developing patellofemoral pain as well. Since triathletes tend to have stronger abdominal, gluteal, and quadriceps muscles from biking and swimming, they tend to have more issues with overuse patellofemoral pain, IT band syndrome, or plantar fasciitis in the foot. To some degree, the cross-training required in triathlon helps strengthen the muscles that protect triathletes from the abnormal mechanics seen in solo sport competitors.

A relatively common and insidious concern for triathletes, or for any other endurance athlete for that matter, is overtraining syndrome. At its worst, this can present as severe, chronic stress with pituitary suppression (decreased hormone levels, increased cortisol). The athlete feels tired, can't recover from training sessions, has elevated morning heart rates, can't reach maximum heart rate during exercise, and has symptoms of depression. There is a continuum of impairment in terms of clinical symptoms from minimal, with minor deficits in performance and mild depressive symptoms, to more significant, with mild immunosuppression (increased infections, etc.) and possible cardiac arrhythmias. Unless the symptoms are very severe, laboratory values are all within normal limits and the diagnosis is clinical. A more acute cardiac version has been seen in long-distance triathletes, who, following a race, have shown transient (6–8 weeks) depressions in cardiac function that fully reverse with rest. Chronic issues with muscle strains of the calf, quadriceps, or hamstring can also relate to insufficient recovery time or overtraining. The likelihood of suffering a more severe tear of a muscle or tendon with training or competition is increased when muscle or connective tissue is compromised and unable to withstand previously tolerated stresses.

A more concerning overuse injury, largely secondary to running, relates to stress fractures. Bone is a dynamic organ, and when impact stress overloads a bone's ability to adapt, a mechanical failure of the structure can occur. This may initially present as an inflammation of the periosteum (the membrane covering the bone). When this happens along the back edge of the tibia, where the soleus and posterior tibial muscles attach, it is called "shin splints." Left unchecked, this accumulation of mechanical stress above that which can be repaired may progress to bone marrow edema and eventually to cortical fracturing. This can occur in the tibia, fibula, metatarsal bones of the foot, tarsal bones of the ankle, pubic rami and symphysis of the pelvis, and femur. As part of the process of adaptation to training, bones become denser and better able to handle the mechanical stress. Thus at a certain level, quality rest/recovery can become just as important as quality training.

Conclusion

In general, triathletes experience the same overuse and traumatic injuries that their single-sport compatriots do. They simply have a larger exposure by training in all three disciplines. There are a few unique aspects associated with the open-water swimming and transitions, but the similarities outweigh the differences.

Andrew Hunt

See also Biking, Injuries in; Heat Illness; Stress Fractures; Swimming, Injuries in

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Trigger Finger

Trigger finger is the most common atraumatic, painful complaint of the hand and the fourth leading reason a person is referred to a hand surgeon. Its incidence is 28 cases per 100,000 people per year, with a lifetime risk of 2.6%. Having diabetes increases this risk to 10%. Trigger finger initially starts as discomfort in the palm that worsens with movement of the digits and progresses to "locking" of the involved digit in flexion. Adults are affected more than children. Women are affected two to six times more than men. The dominant hand is the most commonly affected, and the digits that trigger in descending order of frequency are the thumb followed by the ring, middle, pinky, and index fingers. Peak age of incidence is 55 to 60 years, with a smaller peak under 8 years of age. The usual treatment involves a cortisone injection, which is curative up to 90% for all except individuals with diabetes mellitus and rheumatoid arthritis.

Anatomy

The flexor tendons connect the digits to the forearm muscles and are responsible for bending the digits. A membranous tendon sheath covers the outside of the tendon and is attached to the bones of the hand, starting at the metacarpal head (palm bone) and extending to the distal phalanx (last finger bone). Different areas of the tendon sheath are thickened and function as pulleys to direct the tendon in its path and to prevent bowstringing. Trigger finger occurs when there is a mismatch in size of the flexor tendon, most commonly caused by a nodule, and the pulley. The most common area for the tendon to get stuck at is the first annular (A1) pulley, located over the joint of the metacarpal (palm bone) and proximal phalanx (initial finger bone). Occasionally, triggering can occur at other pulley sites.

Causes

Trigger finger is often idiopathic. It does occur more commonly in people with metabolic problems such as diabetes mellitus and hypothyroidism and different rheumatologic conditions, including rheumatoid arthritis, psoriatic arthritis, amyloidosis, sarcoidosis, and pigmented villonodular synovitis. Interestingly, trigger finger is associated with duration of diabetes and not with sugar control in individuals with diabetes requiring insulin injection. Because repetitive finger movements due to one's occupation or sport can cause high tension across the A1 pulley, it is proposed to cause the development of fibrocartilaginous metaplasia of the pulley and tendon cells, thus creating the mismatch in size. Trigger finger commonly coexists with carpal tunnel syndrome, de Quervain tenosynovitis, and Dupuytren contracture. Sometimes, locking of the digit can occur if ligaments catch on the bony prominence of the metacarpal (palm bone) head, if there is swelling of the tendon at different locations, or if loose bodies are present in the metacarpal phalangeal joint. Rarely, a finger injury involving a laceration of the flexor tendon may present as a trigger finger from the cut portion of the tendon catching at the A1 pulley.

Symptoms

Initially, pain is only felt in the palm at the metacarpal phalangeal joint. The pain can also radiate along the palm or along the digit. Locking of the digit occurs during active flexion-extension activities, often reported to worsen on rising in the morning. The athlete may complain initially of painless clicking of the digit with flexion that progresses to painful catching. Long-standing cases of trigger finger may present as a stiff digit, which the person is unable to bend.

Diagnosis

Trigger finger is diagnosed clinically from a history of locking of the digit and observation of triggering in the physician's office. Sometimes, a nodule on the flexor tendon is felt at the metacarpal phalangeal joint. Snapping or crepitus may be felt along the flexor tendon at the A1 pulley while the finger is passively flexed and extended. Laboratory evaluation is only required if there is suspicion that the nodule is secondary to medical conditions such as diabetes mellitus, rheumatoid arthritis, hypothyroidism, or gout. Occasionally, a radiograph of the hand is performed to look for loose bodies in the metacarpal phalangeal joint and arthritic changes in the metacarpal head or accessory bones of the hand.

Treatment

If the triggering of a digit occurred with a specific activity, then avoidance of that activity will lead to resolution of the symptoms. Otherwise, the first-line treatment recommended involves an injection of steroid medication near the bump on the tendon. Oral or topical anti-inflammatory medications can be tried initially but are often unsuccessful. Splinting the involved digit with 15° of flexion at the metacarpal phalangeal joint can be tried, but this has a lower success rate in those with more severe disease, triggering of longer than 6 months' duration, and multiple trigger digits. Splinting needs to be done continuously for 6 weeks and has a success rate of up to 50%. Injection into the tendon sheath has a success rate of 90%, and if a second injection is required, it is half as beneficial as the first one. Steroid injection has a higher success rate in those with a palpable nodule, if the duration of symptoms is less than 6 months, and if the digit triggering is the thumb. Complications of steroid injection include dermal or subcutaneous fat atrophy, skin depigmentation, infection, and, very rarely, tendon rupture. If trigger finger persists despite the injection, surgical release can be curative and involves cutting the A1 pulley. This procedure is done under local anesthesia in the operating room as either an open or a percutaneous procedure. With the open technique, an incision is made over the A1 pulley site, and the pulley is divided under direct visualization. For the percutaneous technique, a 18-gauge needle is used to divide the pulley without direct visualization. Potential complications of either procedure include digital nerve injury, bowstringing of the tendon (especially if the A2 pulley is divided), infection, hematoma, and persistent pain. Other reasons for surgery to be considered include a digit that is stuck in flexion and cannot be reduced and trigger thumb in an infant. Occasionally, a reduction flexor tenoplasty is performed, which involves cutting out the bulbous swelling of the tendon so that the tendon is smooth and glides without hindrance through the pulley.

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See also Carpal Tunnel Syndrome; Diabetes Mellitus; Finger Sprain

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Trochanteric Bursitis

Trochanteric bursitis is inflammation of the bursa that lies on the outside (lateral) aspect of the hip, known as the greater trochanter of the femur bone. Bursitis can result from both overuse (chronic) and trauma (acute). It is common in all types of athletic and nonathletic populations.

Anatomy

Bursae are small fluid-filled sacs that are usually found around joints or bony prominences. Their purpose is to create lubrication between two uneven surfaces and provide frictionless movement. In this case, the bursa lies between the femur's greater trochanter, which is the hard bony prominence on the outside of the hip, and a strong tendon known as the iliotibial (IT) band. The IT band runs from the top of the hip, down the side of the leg, to the knee. Its main function is to abduct the leg as if to kick one's leg out to the side. However, when moving the hip forward and backward, as when walking, running, swimming, and biking, the IT band tends to rub over the greater trochanter and may irritate the bursa. When the bursa becomes inflamed, it swells and becomes compressed between the bone and the tendon, thus creating pain.

Causes

Trochanteric bursitis is most often caused by overuse or direct trauma. Direct trauma such as a fall that causes the patient to land on the lateral hip region or a direct blow to the outer hip is more common in women and in the middle-aged or elderly population. However, direct trauma is frequently seen in contact and collision sports as well. These falls or blows will cause bleeding (hematoma) into the bursa, which then results in swelling. Usually, these hematomas are rapidly absorbed by the body, but not infrequently, they may result in scarring, adhesions, and calcifications, leading to a more chronic type of bursitis.

More commonly, chronic repetitive trauma is involved, which can occur from merely running or walking. Conditions that predispose patients to this type of trochanteric bursitis include postural abnormalities, which can be caused by scoliosis, degenerative spinal conditions, a wide pelvis (female runners), hip and knee arthritic conditions, leg length differences, flat feet, high-arched feet, overpronation of the feet, or even oversupination of the feet at heel strike. Improperly fitting shoes, worn-out shoes, running on uneven or hard (cement) surfaces, and sudden increases or changes in training are other causes of trochanteric bursitis. Another cause occurs in cycling when the seat is too high and the cyclist has to rock from side to side when pedaling, which results in repetitive sliding of the IT band over the bursa. At times, the bursitis develops spontaneously without any apparent cause.

Symptoms

Patients affected by trochanteric bursitis will complain of a deep ache or burning pain over the greater trochanter on the outside of the hip. It will usually be worse with activity and may be worse both after rising in the morning or after prolonged sitting. It may get better after the first few steps only to recur later after walking for a ½ hour or more. The pain may radiate down the side of the leg toward the knee or ankle or into the buttock. The pain is usually worse at night while trying to lie on the affected side.

Diagnosis

The diagnosis of trochanteric bursitis is usually clinical. A typical history can be confirmed on physical examination. There will be maximal point tenderness to palpation directly over the greater trochanter. Point tenderness just superior to the trochanter is usually more indicative of gluteus medius tendinitis, while point tenderness just posterior to the trochanter is more indicative of piriformis tendinitis. Pain will also be present during gait when the hip goes from flexion to extension. Pain may occur with passive hip adduction, abduction, or external rotation but not with internal rotation. Pain may also be present with active hip abduction. Rarely, a limp will be present.

An X-ray can be obtained to ensure that there are no bone spurs, calcifications, or arthritis that could be contributing to the problem. Occasionally, a magnetic resonance imaging (MRI) scan or a bone scan may be done if the diagnosis is unclear or if the problem does not resolve with treatment. These tests will help rule out tumor, occult fracture, or necrosis of the bone.

Treatment

The goals for treatment include reducing pain and inflammation, as well as preserving mobility and preventing recurrence. Treatment recommendations may initially include a combination of rest, heat and/or cold application, stretching and strengthening exercises, activity and shoe modification, pain medication such as acetaminophen or ibuprofen, and osteopathic manipulation along with correction of any anatomical or biomechanical asymmetry (orthotics/heel lifts). Cross-training incorporating low-impact activity such as biking, swimming, or using elliptical machines can minimize the pain and allow for continued exercise. Typically, resolution of symptoms occurs within 2 to 6 weeks of treatment. For persistent symptoms, more advanced treatments may be required, such as physical therapy, cortisone injections, or surgery.

While only a limited number of controlled studies have proven the usefulness of physical therapy for this condition, a specific and goal-directed program can often reduce symptoms. Physical therapy can be incorporated to teach the patient a home exercise program, emphasizing stretching specific tendons, including the IT band and tensor fascia lata, as well as stretching the external hip rotators, quadriceps, hamstrings, adductors, and hip flexors. Strengthening exercises should focus on the lower abdominals and the gluteal muscles. Other modalities used in physical therapy can also be employed, such as *phonophoresis,* which uses sound waves to allow for deep penetration of topical medications, and *iontophoresis*, which uses an electrical current to allow corticosteroids to penetrate the skin and minimize the inflammation to the bursa. Ultrasound therapy and soft tissue massage may also be helpful.

Cortisone injections are an important option within the comprehensive treatment plan. Randomized, controlled clinical trials have shown that corticosteroid and lidocaine injection for trochanteric bursitis is an effective therapy with a prolonged benefit. Trochanteric bursa injections are often performed without radiographic guidance, and a local anesthetic can first be used as a diagnostic injection. The needle is advanced to the greater trochanter (with contact on the bone being made to confirm depth and appropriate placement) and is then withdrawn slightly so that it is located within the bursa. The local anesthetic can then be injected directly into the bursa. If appropriate relief is achieved, this would be considered confirmation of trochanteric bursitis as the cause of the pain. This injection of local anesthetic can then be followed by the administration of steroids. An injection of 12 to 24 milligrams (mg) of betamethasone or 40 to 80 mg of methylprednisolone is commonly used. This injection may be repeated at 4 to 6 weeks if pain relief has been less than 50%. In most cases, in which the diagnosis of trochanteric bursitis seems straightforward from the clinical evaluation, a diagnostic injection with local anesthetic is not necessary prior to the corticosteroid injection. Patients should be made aware of the risks of injection prior to the procedure.

Surgery is rarely indicated and is often reserved for severe cases that are recalcitrant to months of the conservative treatments discussed above. There are several surgical techniques that have been used in the past. One such technique involves excision of the bursa via incisions in the IT band over the greater trochanter. Another procedure is a trochanteric reduction osteotomy, which removes a portion of the trochanter. Arthroscopic bursectomy is the third option and allows for excision of the bursa using a scope. Finally, release and lengthening of the IT band is another surgical alternative. Surgical intervention carries the increased risk of anesthesia along with the direct surgical risks and should be considered only after appropriate nonoperative interventions have been exhausted.

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See also Gluteal Strain; Hip, Pelvis, and Groin Injuries; Iliotibial Band Syndrome

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Trunk Injuries

Injury to the trunk during sports is common and generally includes muscle and bone injury, but it can also include more serious injury to the internal organs. Examples of muscle injuries include strains of large muscle groups, such as the rectus abdominus and perivertebrals. Bones such as the lumbar vertebrae can sustain chronic injury, as in spondylolysis, or acute injury, as with transverse process fracture in blunt trauma. However, the predominance of musculoskeletal injuries may lead the practitioner to overlook a more serious injury. Below are some important and sometimes life-threatening injuries to be considered in the athlete with injuries to the trunk.

Pneumothorax

A pneumothorax may occur spontaneously during a sporting event or acutely after blunt or penetrating trauma in sports activity. It occurs when air is introduced between the lung and the pleura, the membrane that surrounds the lungs. Depending on the mechanism with which the contact between these two surfaces was compromised, air can accumulate and compress the lung, resulting in chest pain and shortness of breath. This can lead to respiratory failure. If enough air accumulates, the pressure from this trapped air can compress the heart and limit its ability to fill and then pump blood, leading to cardiovascular collapse and death.

Spontaneous pneumothorax is caused by a ruptured bleb at the surface of the lung and leads to escape of air from the lung into the space between the lung and the pleura. It is most common in tall, thin males but can occur in any age-group or gender. It can occur at rest and also during vigorous exercise and can be mistaken for a musculoskeletal chest pain. The athlete generally will complain of moderate to severe pleuritic sharp pain on the left or the right, associated with varying degrees of shortness of breath. Generally, a spontaneous pneumothorax is small and stable, but it can progress to the life-threatening complications described above. The patient needs to be transported to a medical facility where imaging can be done and a thoracostomy performed to relieve the pressure. In the event that immediate transport is unavailable and the patient is experiencing cardiovascular collapse, an emergent decompression needle thoracostomy can be performed by qualified medical professionals.

Traumatic pneumothorax can be caused by blunt or penetrating forces. The force required to cause a pneumothorax from blunt trauma is generally significant and has associated injury, such as rib fractures. Rib fractures require only pain medication as treatment, but all suspected rib fractures require a plain radiograph to rule out the diagnosis of pneumothorax. For penetrating trauma, such as skate-induced chest wall laceration in ice hockey, a plain radiograph should be ordered to rule out the diagnosis of pneumothorax even when suspicion is low for it. Any lacerations or punctures to the chest wall should not be explored, as this can cause a pneumothorax in some cases. Complications and treatment are the same as described above.

Cardiac Contusion

High-speed blunt trauma to the chest can result in injury to the heart, the most dramatic effect of which is sudden death, or commotio cordis. Cardiac contusion in sports is rare but occurs when forces are transmitted from the ballistic (as in baseball) or opposing player (as in American football) to the chest of the athlete. The myocardium is bruised, which causes pain and can affect cardiac output and in rare cases can lead to failure. The diagnosis should be considered in any athlete who complains of chest pain after a high-speed impact. Evidence of significant injury, as with sternal fracture/injury or multiple anterior rib fractures, should increase suspicion of cardiac injury. Emergency evaluation includes a chest radiograph, electrocardiogram, and cardiac enzymes. If there is a high suspicion of cardiac contusion, an echocardiogram may be taken and/or the patient may be kept under observation.

Solid Abdominal Organ Lacerations and Contusions

Blunt trauma to the abdomen can occur in all contact sports, including football, men and women's hockey and soccer, and countless others from professional-level activities to recreational sports such as bodyboarding. Forces transmitted from an object, such as a helmet or a knee, to the abdomen can be absorbed by the liver, spleen, or kidney. In the event that these forces are sufficient to cause bleeding, these organs may become bruised and occasionally lacerate. Lacerations can cause bleeding within the organ and impair the functioning of the organ itself. This is often seen with a kidney laceration, which results in decreased long-term renal function. Occasionally, the bleeding is not contained within the solid organ, and blood accumulates in the abdomen. If the bleeding is brisk or the injury is not identified in time, this bleeding can result in severe blood loss and occasionally in death. If surgery is indicated, attempts should be made to stop the bleeding and preserve organ function. As both are not always possible, occasionally the damaged solid organ will need to be removed.

Solid organ injury should be considered under the right clinical circumstances. In cases where solid organ injury occurs, the history will include a mechanism that fits clinically. Examples of mechanisms of blunt solid organ injury include the impact of a football helmet on the abdomen or back, a high-speed hockey puck to the stomach, or a bodyboard lodged between the abdomen and the beach sand. The athlete will complain of abdominal or flank pain with or without nausea or light-headedness. The abdomen or flank is usually tender, and in cases of significant bleeding, the pulse rate may be high and blood pressure low. Any patient with possible solid organ injury should be transported immediately to a local emergency room.

Hollow Abdominal Organ Injury

Hollow organ injury, specifically large and small bowel trauma, is unusual after blunt trauma in athletics. Historically, the athlete will have a mechanism in which a forceful blunt trauma is sustained to the anterior abdomen. Mechanisms that can cause hollow organ injury include a fall from a bicycle with impact from the handlebars, a surfboard wedged between the sand and the surfer's abdomen, or a knock from a football helmet to the abdomen. In mild cases, the athlete may complain of minimal pain associated with nausea, as in the case of a minor small bowel contusion. In case of a ruptured viscus, the athlete will have severe pain and vomiting. On physical exam, the mild small bowel contusions may be normal save for some tenderness to deep palpation. This is in contrast to the patient with a ruptured viscus, who will have severe tenderness to light palpation, rebound tenderness, as well as other evidence of an acute abdomen. The vital signs may be unstable, with a low blood pressure and fast heart rate. An initial, upright chest X-ray is the fastest and most specific way of determining if there is air in the abdomen, which would indicate a perforated viscus. Computed tomography is the most sensitive study to find evidence of a ruptured viscus, and it will also show evidence of hollow viscus contusion and injury to the solid organs. A hollow viscus perforation is a surgical emergency, whereas a contusion can be monitored clinically.

Gian Corrado

See also Bruised Ribs; Chest and Chest Wall Injuries; Rib Fracture and Contusions

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Turf Toe

The term *turf toe* has become a commonly accepted name referring to a sprain involving the hallux (great toe) metatarsophalangeal (MTP) joint of the foot. The name was first coined in 1976 after it was found that the frequency of injuries to the MTP joint was much greater during competition on artificial playing surfaces. The injury is fairly common; it is seen most often in football, but it also occurs in other sports such as wrestling, basketball, and dance, among others. Because this particular joint plays a key role in running, sprinting, and cutting, an injury can result in significant functional disability. It is thought to be underreported and not always appreciated as the significant injury that it may be or can become if it is not appropriately managed.

Anatomy

The anatomy of the forefoot is intricate and quite complicated. The MTP joint of the hallux involves a metatarsal (long bone) with a rounded, cartilage-covered surface at the end, which joins with the concave base of the phalanx (toe bone). Stability of the MTP joint comes from medial (inside) and lateral (outside) collateral and metatarsosesamoid ligaments in addition to a strong plantar plate. There are also several different muscle tendons that run along either side and underneath the joint, attaching onto the phalanx. These structures together make up the intricate capsuloligamentous complex of the first MTP joint.

Motion in the joint consists primarily of plantarflexion (downward) and dorsiflexion (upward). Passive range of motion varies widely from 3° to 43° of plantarflexion and from 40° to 100° of dorsiflexion.

Causes

The two primary causes of turf toe are the advent of artificial playing surfaces and the coinciding introduction of flexible-soled turf shoes. Artificial playing surfaces were introduced in the 1960s, and with that came a dramatic increase in the number of turf toe injuries. This is due to the increased friction caused by the artificial surface and shoe interface. When artificial turf was introduced, players were typically wearing a grass cleat with a metal plate in the sole, which attached to the cleats and added stability to the forefoot. After playing on the artificial surface, players complained of traction problems, which led to the introduction of a flexible turf shoe. Both caused the incidence of turf toe injuries to increase dramatically.

As artificial turf ages, it stiffens. This has also been thought to contribute to the increasing incidence of turf toe injuries, although studies have not validated this hypothesis. Since natural playing surfaces are once again becoming the standard, it is expected that turf toe injuries will also decrease.

Mechanism of Injury

The most common mechanism of injury is hyperextension of the great toe. This often occurs with tackling in American football, where the forefoot is fixed on the playing surface with the heel raised in a dorsiflexed position. A force from the tackler is thus directed down the lower leg into the foot, causing an exaggerated dorsiflexion and subsequent hyperextension of the great toe. This hyperextension can lead to varying degrees of injury to the plantar plate, capsule, and collateral ligaments or the cartilage surface of the bone.

Although most turf toe injuries occur with hyperextension, other mechanisms have been described as well. Hyperflexion, or "sand toe" (termed so because of its high propensity in sand volleyball players), injury is sometimes considered a variation of turf toe, although it often has a different clinical course and, thus, may need to be considered separately.

Varus (bending inside) and valgus (bending outside) are two other described mechanisms. Valgus is most commonly seen in a football lineman who is pushing off from a stance. Varus is rarely seen but can occur when an outward force is applied to a fixed forefoot.

Diagnosis

The diagnosis is made by first eliciting how the injury occurred and, if available, watching a video replay of the incident. Patients may present with a single acute or multiple episodes of trauma. Classically, the MTP joint will exhibit tenderness, swelling, and pain with movement. At this point, if a turf toe diagnosis is suspected, X-rays with several different views should be obtained to assess for a capsular avulsion, sesamoid fracture or migration, impaction injury, or separation of a bipartite sesamoid. A magnetic resonance imaging (MRI) scan is usually ordered if there are abnormalities on X-ray. MRI is the best tool to assess soft tissue and cartilage damage, as well as further evaluate for bony abnormalities. This will aid in grading the injury, as well as formulating a treatment plan and making an overall prognosis.

Most injuries are graded on a scale of I to III, with III being the most severe. Grade I is a stretch injury to the capsuloligamentous complex, with minimal symptoms associated with it. Grade II is a partial tear to the capsuloligamentous complex, with pain with weight bearing, bruising, and restricted range of motion. Grade III is a complete tear of the capsuloligamentous complex, with an associated disruption of the plantar plate from the metatarsal neck, impaction of the phalanx into the metatarsal head, and sometimes movement of the sesamoids. There is severe pain, swelling, bruising, and motion restriction, along with inability to bear weight.

Treatment

The initial treatment of an acute turf toe injury should include the RICE protocol of *r*est, *i*ce, *c*ompression, and *e*levation. Athletes with Grade I injuries often can return to play immediately, although often toe taping and/or using a stiff insole may be necessary or desired for protection. Grade II injuries will often require up to 2 weeks of rest. Patients with Grade III injuries should remain non–weight bearing for several days and have prolonged rest, usually for 4 to 6 weeks. The athlete should slowly progress from walking to running to cutting and, finally, sport-specific activities. Painfree range of motion of 50° to 60° of upward flexion has also been proposed as a criterion for returning to play. Operative treatment is reserved for the most severe turf toe injuries, including large capsular avulsions with an unstable joint and diastasis of a bipartite sesamoid, or after conservative therapy has failed.

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See also Foot Injuries; Hammertoe; Musculoskeletal Tests, Foot

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Ulnar Neuropathy

Ulnar neuropathy is inflammation or compression of the ulnar nerve, resulting in paresthesia (numbness, tingling, and pain) in the outer (ulnar) side of the arm and in the hand near the little finger. The ulnar nerve provides motor control to the muscles in the forearm and hand. It also provides the sensations of touch, temperature, and texture to the volar surface, or undersurface, of the forearm, the palm, and specifically the fourth and fifth digits of the hand circumferentially. Ulnar neuropathy that originates at the elbow is most common, although it can also be caused by injury to the nerve as it passes through the wrist.

Approximately 40% of Americans experience some form of ulnar neuropathy at least once during their lifetime. While the ulnar nerve is structurally identically in men and women, men tend to develop ulnar neuropathy more than do women. The reason may be that men generally have less fat overlying the elbow to protect the exposed nerve, or it may be due to differences in work- or sports-related stresses. The onset of ulnar neuropathy is often insidious. As a result, many of those who are affected are middle-aged or older adults. Demographic risk factors include a family history of diabetes, alcoholism, and HIV (human immunodeficiency virus) infection. Direct compression from pressure on the elbow can trigger ulnar neuropathy; therefore, people who have desk jobs and spend extended periods of time working on computers are at risk of developing the disorder. Ulnar neuropathy is variously known as *bicycler's neuropathy, cubital tunnel syndrome, Guyon canal syndrome,* and *tardy ulnar palsy*. Its occurrence is most notable in cyclists from prolonged compression on the nerve while gripping the bicycle handlebars; yet it is often seen in sports such as tennis, baseball, softball, and golf, where a significant amount of time is spent gripping sports equipment.

Anatomy

The anterior primary rami of the eighth cervical and first thoracic (C8 and T1) vertebrae contribute to form the medial cord of the brachial plexus. The medial cord leaves the axilla as the ulnar and median nerves. Though the ulnar nerve starts from the cervical nerve roots, its target motor and sensory innervations are located in the medial forearm and hand. The ulnar nerve travels along the posteromedial aspect of the arm, pierces the intermuscular septum, and courses beneath the medial head of the triceps. It enters the elbow at the ulnar groove between the medial epicondyle and olecranon. Then the nerve passes through the cubital tunnel into the forearm deep into the flexor carpi ulnaris. At the wrist, the ulnar nerve enters the hand distal to the ulnar styloid through the Guyon canal. The ulnar nerve is most susceptible to injury at these two tunnel sites. The muscles innervated by the ulnar nerve are the flexor carpi ulnaris, the flexor digitorum profundus, the palmaris brevis, the interossei muscles, the medial two lumbricals, the flexor

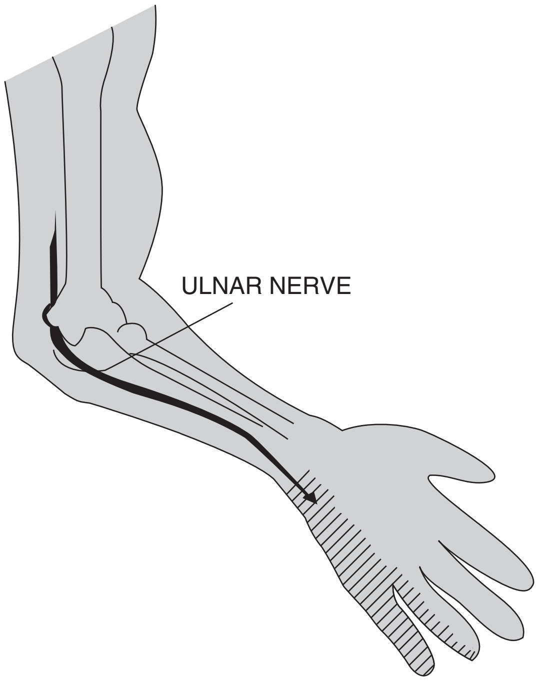

Figure 1 Course of Ulnar Nerve, Showing Sensory Innervation in the Forearm and Hand

pollicis brevis, the adductor pollicis, and the hypothenar muscle group. The ulnar nerve provides sensory innervation to the medial palmar and dorsal aspects of the forearm (including the elbow) and hand and supplies sensation to the small finger and medial one half of the ring finger (Figure 1).

History and Physical Exam

Ulnar nerve injuries can present initially as paresthesias anywhere along its sensory distribution. A typical complaint would be a feeling of "pins and needles" over the ring and small finger or medial forearm. Symptoms can include pain, weakness, and fine motor deficits. On examination, there may be clawing of the ring and small fingers or wasting of the intrinsic hand muscles.

Injuries at any point along the ulnar nerve can have distal manifestations in the hand and fingers. This makes it difficult to pinpoint the exact site where the ulnar nerve is injured. One exception is lesions that occur at the Guyon canal. The dorsal cutaneous sensory branch of the ulnar nerve leaves the main ulnar nerve prior to the Guyon canal. Therefore, lesions at or distal to the Guyon canal would not present with dorsal sensory deficits. Identifying the correct location where ulnar nerve function is compromised affects rehabilitation and treatment recommendations. Other conditions in the differential diagnosis for ulnar neuropathy should be worked up if suspected, including C8-T1 radiculopathy, brachial plexopathy, thoracic outlet syndrome, peripheral polyneuropathy, and overuse syndromes.

There are certain provocative tests that may trigger ulnar nerve symptoms and help localize the lesion. These tests include the following:

- *Elbow flexion test:* Similar to the Phalen test for the median nerve and carpal tunnel syndrome, this maneuver can elicit symptoms due to cubital tunnel syndrome. The elbow is placed in full flexion with wrist extension for 3 minutes. A positive test is when numbness, tingling, and/or pain occur over the ulnar distribution.
- *Froment sign:* The patient is asked to hold a piece of paper between the thumb and the index finger. Patients with ulnar nerve injury will have difficulty holding onto the piece of paper and will compensate with the flexor pollicis longus muscle by flexing at the thumb's interphalangeal joint.
- *Tinel sign:* Percussion over the ulnar groove, medial epicondyle, cubital tunnel, or Guyon canal may reproduce symptoms. This is a very nonspecific test with variable results.
- *Wartenberg sign:* The small finger is in an abducted position at rest due to muscle weakness and asymmetric pull from unaffected muscles.

Imaging and Testing

Radiographs of the upper extremity are often obtained, but in the absence of associated musculoskeletal trauma, they rarely demonstrate abnormalities that aid in the diagnosis or treatment of ulnar neuropathy. The most frequent findings demonstrate degenerative changes, fractures, or bone spurs that can contribute to nerve impingement. Conversely, electrodiagnostic tests, such as nerve conduction studies and electromyography

(EMG), are extremely helpful to accurately localize the lesion and determine the severity of injury. Occasionally, there are multiple sites of injury to the ulnar nerve that can be distinguished on electrodiagnostic testing.

Specific Ulnar Nerve Injuries

Some specific ulnar nerve injuries are listed below.

- *Ligament of Struthers.* As the ulnar nerve passes through the intermuscular septum in the upper arm, it passes under a tough fascia layer called the arcade or ligament of Struthers. Here, the ulnar nerve can become entrapped. Conservative management tends to yield poor results; therefore, a surgical release of the ligament is often necessary.
- *Ulnar Groove.* The ulnar groove is a common site for ulnar nerve injury. Here, the nerve is at risk of being injured by direct trauma (fractures), traction injury such as valgus stress at the elbow from throwing (valgus overload syndrome), and recurrent subluxation of the nerve in and out of the groove. Compressive injury can occur at this site from leaning on the elbows or from the application of a tight cast, splint, or brace. Elbow flexion often reproduces or exacerbates the painful symptoms. Treatment options begin with conservative pain management and occupational therapy to maintain elbow range of motion and forearm strength. Biomechanical evaluation and loose protective padding or splinting around the elbow can help reduce the symptoms. Surgery (ulnar nerve release or ulnar nerve transposition) may be indicated if conservative treatment fails.
- *Cubital Tunnel Syndrome.* The ulnar nerve enters the forearm through the cubital tunnel under the medial epicondyle and olecranon. The borders of the cubital tunnel are the two heads of the flexor carpi ulnaris, the medial collateral ligament of the elbow, and the pronator aponeurosis. Ulnar nerve entrapment can occur anywhere along this tunnel. Injuries are typically due to repetitive motion. Treatment tends to be conservative and similar to the treatment, described above, for ulnar groove injuries. A surgical cubital tunnel release is reserved for those who fail conservative management.
- *Guyon Canal Compression.* The Guyon canal is formed by the pisiform bone, the hook of the hamate, the flexor carpi ulnaris, and the carpal ligament. The dorsal cutaneous sensory branch of the ulnar nerve leaves the main ulnar nerve proximal to the Guyon canal. Therefore, compressive lesions at or distal to the Guyon canal would not present with dorsal sensory paresthesias. Bicycle riding (*handlebar palsy*), push-ups, ganglion cysts, or lipomas can all cause ulnar nerve compression at the Guyon canal. Treatment includes activity modification (wrist padding or holding the handlebar from the side position instead of the top), stretching exercises, and nonsteroidal anti-inflammatory drugs (NSAIDs). Surgical interventions can be considered if symptoms fail to improve.
- *Hypothenar Hammer Syndrome.* Hypothenar hammer syndrome is caused by repetitive impact on the hand causing ulnar nerve injury at the Guyon canal. In addition to nerve injury, there can also be distal ischemia with arterial thickening, thrombosis, and possible aneurysm formation. In addition to the symptoms above, other complaints may include cold intolerance and pain over the palm of the hand. Treatment adjuncts to the above include vasolytic agents or vascular repair.

Conclusion

Ulnar nerve injuries are common. While the presenting symptoms are similar in most cases, it is essential to identify the exact anatomic location of compression or injury in order to properly treat this condition. Athletes who present with signs and symptoms of ulnar neuritis or ulnar neuropathy are often difficult to treat due to the frequent repetitive nature of the trauma induced from gripping sport-specific equipment. Modifications in grip technique as well as padding and other adjustments may help significantly alleviate the symptoms of this condition. When the etiology of the ulnar neuropathy is unclear, electrodiagnostic testing is helpful and should be performed. Referral to a sports or orthopedic specialist is indicated for refractory and frequently reoccurring cases.

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See also Elbow and Forearm Injuries; Handlebar Palsy; Musculoskeletal Tests, Hand and Wrist; Wrist Injuries

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Ultimate Frisbee, Injuries in

Ultimate Frisbee (also known as *Ultimate,* in reference to a disc brand sometimes used in the sport) is a noncontact sport that is played in 42 countries by hundreds of thousands of men, women, and youth. In 2007, it was estimated that 824,000 people in the United States reported playing Ultimate at least 25 times a year. The Ultimate Player's Association (UPA) is the national governing body of the sport in the United States, while the World Flying Disc Federation (WFDF) provides international governance for the sport. Ultimate is played formally at the club, college, master's, and youth levels. In 2001, Ultimate debuted as a medal sport at the World Games in Japan.

Overview of the Sport

It is generally agreed that the sport was developed in 1968 on the east coast of the United States, and the first official rules for the game were codified in 1970. Despite having spread worldwide, the sport has had very little media coverage and is unfamiliar to many people. A brief overview follows.

The game is typically played by two teams of seven individuals on a regulation field that is 70 yards (yd; 64 meters [m]) by 40 yd (36.6 m) with end zones 25 yd (22.86 m) deep, approximating the dimensions of an American football field. Though any surface, indoors or outdoors, may be used, generally an Ultimate game is played outdoors on a grass field (variants of the traditional game include indoor and beach Ultimate). A plastic disc (the "Frisbee") whose regulation weight is 175 grams is used. Individuals try to advance the disc down the field, and scoring is achieved each time the offense completes a pass into the defense's end zone. Substitutions are allowed after scores or during injury time outs. A game is won when a specified number of points are accumulated (typically an odd number from 13 to 21), with two clear points on the opponents score, or after 80 minutes of play.

Physical contact between players, including picks and screens, is minimized in the game. The offense may advance the disc in any direction by completing a pass to a teammate. Players may not run with the disc after catching it. If a pass is not caught by a teammate, the defense immediately takes over possession and becomes the offense. Change of possession can also occur by the defense intercepting a pass or when an individual holds the disc for longer than 10 seconds. Ultimate is thus a transition game like basketball.

Several unique rules of Ultimate bear special mention. The game is self-refereed; that is, players are responsible for resolving any disputes at all levels of the game. Calls are typically made within the flow of play. There are clear rules for resolution of disputes, so self-refereeing does not lead to extended discussion or uncertainty about how to continue. The game, therefore, is interrupted much less frequently than many other team sports.

True to its origins in the countercultural 1960s, Ultimate is a sport that aims to be inclusive (teams are often of mixed gender) and in some important respects de-emphasizes competition. The sport places a high value on sportsmanship and fair play, codifying this in the rules as an overriding ethic known as the "Spirit of the Game." Ultimate players are often serious, motivated, and competitive athletes who nevertheless place a premium on the basic joy of play. According to Ultimate Players Association's *Official Rules of Ultimate* (11th edition), "such actions as taunting opposing players, dangerous aggression, belligerent intimidation, intentional infractions, or other 'win-at-all costs' behavior are contrary to the Spirit of the Game and must be avoided by all players" (sec. I. Introduction: B. Spirit of the Game, p. 2). Though this has not been studied, it may be expected then that there might be fewer injuries incurred consequent to fighting among players.

It can be difficult to find other sports with which to compare Ultimate. The sport combines the nonstop movement and athletic endurance of soccer with the aerial passing skills of football. Some commentators have even compared the game with rugby: Though widely dissimilar in their approach to contact, both games involve plenty of running and frequent, deliberate diving to the turf. Some rules of the game, such as self-refereeing and the codified sportsmanship ethic, are almost unique. Overall, Ultimate is a team sport fulfilling the expected requirements of a team sport such as soccer—for example, skill, fitness, sportsmanship, and organization.

Injuries

Like other sports defined as "noncontact," there is ample opportunity for Ultimate players to be involved in collisions, either with each other or with the ground. The nature of the game involves frequent cutting and sprinting, which can inevitably lead to muscle strains, ankle sprains, and knee injuries.

It is a common practice in Ultimate to dive full-length, propelling one's body horizontal to the ground, to catch a low disc. This maneuver is a signature moment in an Ultimate game, and is known as "laying out" or "going ho" (as in "going horizontal"). Laying out is a skill, like sliding in baseball, that can be taught properly: As the disc is caught, the whole body rolls in a twisting motion as it hits the ground, dissipating forces over a broad area from the ulnar aspect of the forearm to the torso and buttocks. Predictable consequences, including shoulder, arm, and rib injuries or severe friction injuries to the skin, can result if the layout is not executed correctly.

To perform at high levels, the player must be fit. As a transition game with little stoppage time, Ultimate places unresearched but predictable demands on the body. While on the field, players are almost continuously moving and are frequently sprinting. In terms of strenuousness, Ultimate would likely then have similar physiological demands to soccer, another high-dynamic/low-static sport. It would be expected that players attempting Ultimate without the requisite levels of endurance, strength, speed, and flexibility would put themselves at higher risk of injury.

Unfortunately, there has been little research done on the injury patterns seen in Ultimate. A review of the relatively sparse literature found two surveys of injuries seen in the sport; the references can be found in the Further Readings at the end of this entry.

The first survey, published in 1991, assessed injuries that occurred in tournaments played in Europe from 1986 to 1990. The survey reported the following:

- Of all injuries, 66.6% affected the lower limbs; the most common injury involved a strain of the thigh muscle.
- Skin injuries, including friction burns, occurred at a higher rate than seen in other similar sports.
- "Minor" knee ailments such as patellar bursitis were more common than "major" injuries such as anterior cruciate ligament (ACL) tears.
- The pattern of knee injuries in general was quite different from that of many other sports and was found to be predominantly overuse injuries.

This study noted that three factors appeared to have the greatest influence on the sport's injury pattern: (1) the preparticipation fitness level of the player, (2) the organization of a tournament and squad size (more games and smaller squads allowing fewer substitutions, resulting in more frequent injury), and (3) the state of the field (hard, packed, and stony fields causing more skin and soft tissue injuries).

The study went on to recommend injury prevention practices, including clothing such as bike shorts and soft protectors on the elbows and knees to minimize the skin exposed to trauma. Though this has not been studied, such protective measures would be expected to minimize the number of lacerations, abrasions, and incidents of bursitis seen in the sport.

The second study, published in 2006, was based on a self-reported survey administered to athletes at an American tournament sponsored by the UPA in 2002. The survey asked players to report retrospectively injuries sustained in their careers; the study reported the following:

- Of the players surveyed, 71% had sought medical care.
- Eighty-eight percent had missed an Ultimate game or practice due to injury.
- Injuries included muscle strains (76%) and ankle (65%), knee (53%), shoulder (37%), head (30%), and rib (21%) injuries.
- A third of shoulder injuries occurred from a "layout" maneuver.
- A third of head injuries resulted in concussion.

The authors concluded, "The results of this survey demonstrate that Ultimate Frisbee injuries are common, that players are plagued with recurrent injuries, and that medical care is often sought."

Both studies noted that hand injuries were surprisingly infrequent. Given the fact that players must catch a typically fast-moving, hard plastic disc or as defenders be expected to block a throw at the point of release, hand injuries might be expected to be more common; however, in the British study, the rate of injury to the hand was only 5.7%, and in the American study, the rate was 8%.

Ultimate, like many other sports, can put participants at risk from environmental hazards, such as heat illnesses and lightning strikes. Other entries in this encyclopedia can be consulted to review the management of these conditions.

An unusual tradition in tournament Ultimate bears a final note: One of the regular prizes given out at some tournaments is for the "worst injury." Like "extreme sports" such as snowboarding or surfing or like a conventional and rugged sport such as rugby, there is a cultural emphasis in Ultimate on injuries as almost a badge of honor. Injuries preventing participation are not valued as they keep the participant from playing; but a laceration or severe abrasion that does not prevent play can be storied. Some have speculated that in such sports, injury rates may be higher as participants seek this unique "reward," playing intensely or beyond the limits of their endurance. It would be interesting to do more research on this phenomenon.

Overall, much more study specific to sports medicine is needed in this relatively new and growing sport. Increased injury surveillance can better elucidate injury patterns, and subsequent preventive measures might be put in place. Research into preparticipation conditioning levels might inform injury prevention practices. Investigations into environmental hazards or protective clothing might likewise reduce injury rates. Unique aspects of the sport—the "Worst Injury of the Tournament" award and "The Spirit of the Game"—could be studied and their effect on injury patterns and athletic health elucidated.

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See also Ankle Injuries; Foot Injuries; Knee Injuries; Overtraining

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World Flying Disc Federation: http://www.wfdf.org

Ultrasound

Ultrasound technology has been used widely in the medical field for visualization and diagnosis of many conditions, including pregnancy, abdominal problems, and blood clots. More recently, the use of ultrasound in diagnosing and treating conditions in sports medicine has become more prevalent. Ultrasound imaging provides excellent visualization of tendons, ligaments, muscles, nerves, certain joints, and bones. It is exceptionally helpful in diagnosing tendon damage, ligament tears, and muscle strains. Sports medicine physicians frequently use ultrasound to make a particular diagnosis and guide their treatment recommendations.

Ultrasound technique

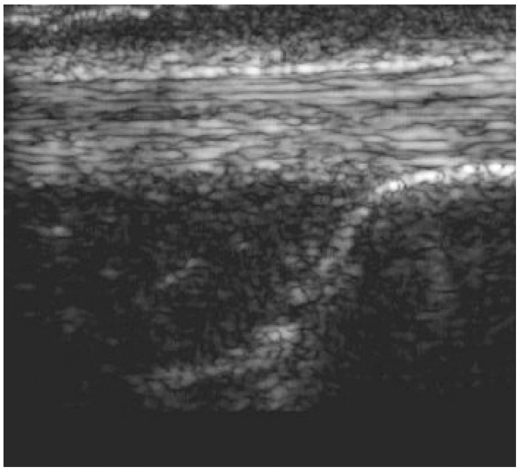
Source: Photo courtesy of Joel M. Kary, M.D.

Ultrasound Principles

An ultrasound machine uses a transducer that is connected to the monitor and computer of the machine (see photo, top of right column). The transducer is the device actually applied to the skin, using coupling gel, when images are being obtained. Electrical energy is transformed into sound waves by crystals in the transducer. This is called the piezoelectric effect and is fundamental to all ultrasound technology. Ultrasound is unique because it uses these sound waves to produce an image instead of using radiation, which is used for producing images for X-rays or computed tomography (CT). Ultrasound waves penetrate the skin and reflect back to the transducer after hitting certain tissues under the skin. This reflection of sound waves is converted into the images seen on the screen when performing a diagnostic ultrasound exam. Tissue that reflects the sound waves strongly appears bright white and is considered *hyperechoic*. (see image, bottom of right column). Tissue that poorly reflects sound waves appears dark and is considered *anechoic*. Tissue that falls somewhere in the middle of this spectrum is considered *hypoechoic*. Transducer frequency is an important concept for diagnostic ultrasound and is measured in megahertz (MHz). The higher the frequency of the transducer, the higher the resolution of the images obtained. However, higher-frequency transducers do not penetrate very deep, which limits the depth at which images can be obtained. Lower-frequency transducers penetrate deeper but do not provide as good image resolution as higher-frequency transducers.

Tendon Pathology

Athletes frequently encounter the pain of tendinitis when training and competing in their chosen sport. Tendinitis that does not heal well can become chronic, developing into tendinopathy. Tendinopathy occurs after the inflammatory response by the body has stopped but the tendon has not fully healed. Ultrasound demonstrates very well the changes associated with tendinopathy, such as partial tears, thickening, and cyst formation. Tendons normally appear as hyperechoic structures with fiber-like architecture and are imaged well with ultrasound due to their close proximity to the skin surface. A normal tendon will appear as smooth parallel lines of fibers without interruption or thickening, as demonstrated in the image of the Achilles tendon.



Normal Achilles tendon viewed with ultrasound. (Note that the image is necessarily of low resolution.)

Source: Photo courtesy of Joel M. Kary, M.D.

Tendinopathy, commonly found in patellar, quadriceps, and Achilles tendons, will appear thickened with areas of hypoechogenicity. Abnormal blood vessel formation sometimes occurs with tendinopathy, and this can be picked up using power Doppler settings. Power Doppler provides visualization of small blood vessels with slow flow rates, which is typical of abnormal blood vessels in tendinopathy. Ultrasound is superior to magnetic resonance imaging (MRI) when imaging tendons because it can provide high-resolution images of the individual fibers of the tendon. Tendon ruptures and tears also occur commonly in athletes. Once again, ultrasound images will clearly visualize the disruption of the tendon fibers and any blood filling the tear. In addition, the tendon can be viewed in motion while obtaining ultrasound images, providing a dynamic nature to the examination. This can be helpful in determining the size of the tendon tear and how many fibers are still intact. Rotator cuff tendon tears of the shoulder are common and are easily visualized using ultrasound.

Ligament Pathology

Ligaments appear as hyperechoic, tightly arranged, fibrillar structures providing a soft tissue connection between bones. Ligament sprains and tears occur in many sports, especially in those involving sprinting, sudden changes of direction, and jumping. Ultrasound provides excellent imaging of the superficial ligaments found in the elbow, ankle, and knee. Complete rupture of a ligament will appear as an interruption to the ligament fibers, usually with local fluid collection from the tear. Ultrasound provides an advantage, in comparison with other imaging modalities, when evaluating ligament tears. Because ultrasound allows for dynamic motion during evaluation, the ligament can be put under stress, and the amount of joint opening can be assessed. This is very helpful in determining the grade of a ligament tear and in prescribing appropriate treatment. Common ligament tears that can be diagnosed by ultrasound include the medial and lateral collateral ligaments of the knee, the ligaments of the ankle, and the ulnar collateral ligament of the elbow.

Muscle Pathology

Muscle tissue can be damaged during sports by a direct blow or sudden movements causing a tear. Muscle strains are exceedingly common in athletic participation and are readily visualized with ultrasound. Under visualization with ultrasound, muscle tissue appears as hypoechoic bundles separated by hyperechoic planes of tissue. Described another way, when viewed in long axis, muscle appears like veins in a leaf, and when viewed in cross section, it appears like a "starry night" pattern. A direct blow to a muscle can lead to accumulation of blood within the muscle tissue, known as a *hematoma*. This is seen as an anechoic or dark fluid collection within the muscle fibers and can be measured using ultrasound. Muscle tears are seen as discontinuity of the muscle fibers and can be accentuated by pressure from the transducer when doing an ultrasound examination.

Advantages of Ultrasound

The use of magnetic resonance imaging (MRI) or computed tomography (CT) in evaluating sports injuries can be quite expensive. In comparison, ultrasound is a less expensive imaging alternative providing superior images of many common sports injuries. Claustrophobia can be ruled out with patients undergoing ultrasound examination, which is done with the athlete seated or lying down on a comfortable exam table. Ultrasound examination can actually be performed as an extension of the physical exam, providing additional valuable information to the clinician. The body part being examined can be viewed in motion with ultrasound, observing the soft tissue and bony anatomy in "real time." This is particularly helpful in making the diagnosis of athletic injuries, the symptoms of which only occur when the tendon or muscle is in motion, such as a dislocating ankle tendon or a shoulder rotator cuff tendon getting compressed during the throwing motion. Another advantage of ultrasound is the ability to quickly perform comparisons of the injured body part with the uninjured side. As the technology has improved, ultrasound units have become more portable while still maintaining superior image quality. This portability is convenient in sports medicine as the unit can be used readily in the athletic training room or on the sideline. Ultrasound can be used to guide injections. The needle can be visualized during the entire injection, thereby ensuring accurate placement of the injection and avoiding damage to any nearby blood vessels or nerves.

Limitations of Ultrasound

The accurate use of ultrasound is operator dependent, and it requires extensive training and practice to become proficient. Errors can be made by not recognizing the difference between normal and abnormal anatomy. Athletes with a large body habitus provide a unique challenge as ultrasound waves have trouble penetrating deep enough to provide adequate images for diagnosis. Due to the inability of ultrasound waves to penetrate through bone, the visualization of deep joint structures and bone is best done using other imaging techniques such as X-ray, MRI, or CT.

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See also Achilles Tendinitis; Achilles Tendon Rupture; Joints, Magnetic Resonance Imaging of; Strains, Muscle; Tendinitis, Tendinosis

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Urticaria and Pruritus

Urticaria, or "hives," represents a dermatologic allergic reaction, of which there are specific types. They are typically pruritic, white, or red nonpitting plaques.

Urticaria is caused by dilation of blood vessels and edema within the epidermis. Classic hives are typically 10 to 15 millimeters (mm) in diameter, will blanch with pressure, and typically result from an allergic trigger. For athletes, classic urticaria may result from exposure to medications such as aspirin or nonsteroidal anti-inflammatory drugs (NSAIDs), which may lead to mast cell degranulation. However, urticaria more commonly associated with exercise and sports are often smaller—2 to 4 mm typically. It is also known as *cholinergic urticaria.*

Cholinergic urticaria is part of a subgroup of urticaria known as *physical urticarias,* which are caused by physical stimulation. Physical urticarias represent 17% of all urticarias, and are most often seen in young adults. They include dermatographism, immediate-pressure and delayed-pressure urticaria, localized or generalized heat-induced urticaria, exercise-induced anaphylaxis, solar urticaria, X-ray–induced urticaria, and argon–laser induced urticaria. A person may have several types of physical urticarias, such as cholinergic urticaria along with solar urticaria. About 80% of all urticaria are idiopathic. About 10% to 20% of the population will suffer from urticaria at some point in their lifetime. If urticaria lasts for 6 weeks or more, it is defined as *chronic.* Chronic urticaria is most often idiopathic.

Cholinergic urticaria occurs when vasodilation of capillaries in the superficial dermis leads to increased transudate. It typically occurs when an antigen is bound by immunoglobulin (IgE) to release histamine from mast cells or basophils. As histamine levels increase, the level of pruritis also increases. Other factors, such as prostaglandins, leukotrienes, platelet-activating factor, and bradykinin and the complement system are also involved.

Cholinergic urticaria occur with any increase in core body temperature, which can occur with exercise. Aerobic activities and exercising in a hot environment are more likely to elicit urticaria. It is characterized by 2 to 4 mm wheals surrounded by large flares. It often starts within 2 to 3 minutes of exercise initiation, and starts on the thorax and neck and then spreads to the rest of the body. Tingling, itching, or a burning sensation on the skin may occur before the hives develop. The hives may coalesce, in which case they will resemble angioedema.

Wheezing and dyspnea may also develop in cholinergic urticaria. It may be difficult to identify cholinergic urticaria if the hives do coalesce. Those who are prone to cholinergic urticaria often also develop the same urticarial reaction with anxiety, a hot shower, sweating, or with any other elevation in body temperature. It is important to take a good history to determine if there are other triggers, such as with hot baths and showers, or with emotional stress and anxiety, or with ingestion of hot or spicy foods, to distinguish cholinergic urticaria from EIA (Exercise-induced anaphylaxis). Cholinergic urticaria is classically reproducible with exercise, stress, or hot showers, while EIA is not. There may be other signs of cholinergic stimulation, such as lacrimation, salivation, and diarrhea.

Cold urticaria is another type of urticaria that can be seen in athletes. It primarily occurs in cold-weather sports or in swimming. Wheals can be large or small, but they are generally confined to the area exposed to the cold. Diagnosis can be made with observation of hives on skin after 5 minutes of cold application and subsequent skin rewarming. The treatment consists of avoiding cold exposure and wearing protective warm equipment, as well as antihistamines.

The gold standard for diagnosis of cholinergic urticaria is passive warming, either in a warm bath or a sauna. An increase in the core body temperature of 0.7 °C to 1 °C is needed. In case there is a possibility that exercise-induced anaphylaxis is the true diagnosis, testing should be done under controlled conditions, with epinephrine, rescusitative equipment, and medical personnel at hand, and a IV set should be in place. Another test that is diagnostic is the methacholine test, where an intradermal injection of 0.01 milligram (mg) methacholine produces localized hives. However, the sensitivity is only about 30%. The passive heat challenge is the best test.

Treatment of cholinergic urticaria consists of avoidance of triggers primarily, such as bathing in hot water, and strenuous exercise in hot weather. Hydroxyzine, an H1 histamine antagonist, is an anticholinergic that has been shown to be most effective at reducing urticarial hives. Hydroxyzine, which is typically dosed at 100 to 200 mg over a 24-hour period, is most effective. In cases refractory to hydroxyzine, danazol anabolic steroid could be effective, but this treatment should be avoided at all costs, considering the side effects. Cyproheptadine may be used as adjunctive treatment if there is associated cold urticaria. Treatment of pulmonary symptoms with cromolyn sodium can be effective. For long-term treatment, an exercise program with gradual increases in duration and intensity may be effective in producing tolerance. Avoidance of obvious triggers, such as NSAIDs or aspirin before exercise is essential. Exercising with an EpiPen if there is any concern for EIA is important. However, care must be taken in athletes competing at NCAA (National Collegiate Athletic Association), Olympic, or professional levels to avoid certain medications that may be banned or restricted, such as anabolic steroids, albuterol, or decongestants.

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See also Allergic Contact Dermatitis; Allergies; Anaphylaxis, Exercise-Induced; Skin Disorders, Metabolic

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V

Vegetarianism and Exercise

Vegetarian diets are common among athletes. A balanced vegetarian diet, meaning one guided by thoughtful and informed food choices, certainly may meet the needs of athletes and even be the foundation for some healthful lifelong habits. For young athletes, however, because growth is still occurring, the priority is to provide enough calories and nutrients for optimal growth and development while still supporting higher activity needs. This entry discusses the vegetarian diet as it relates to sports nutrition.

Individuals choose vegetarianism for a wide variety of reasons. Some of these include health benefits such as the prevention of certain chronic diseases, cultural beliefs, family practices, peer influences, and animal rights or environmental issues. Some athletes insist that a vegetarian diet may improve their performance. Others adopt a vegetarian diet to meet the increased carbohydrate demands of training or to assist in weight control. Of concern are those athletes who describe their dietary intake as "vegetarian" to hide restrictive dietary intake or to mask disordered eating behaviors.

Types of Vegetarian Diets

Many foods meet the criteria for a vegetarian diet. The term *vegetarian* is used to describe diets based exclusively on plant foods to those containing some animal foods. Table 1 outlines various vegetarian diets.

Vegetarian Diets and Performance

While there is no evidence that being a vegetarian gives any direct athletic advantage, healthy vegetarian athletes can perform as well as nonvegetarian athletes. A plant-based or vegetarian diet may be ideal for performance as it is generally high in complex carbohydrates. Only the caloric needs change, as plant-based diets are low in fats. Added fat, especially in the form of monounsaturated fats (olive oil, avocados, nuts, and peanuts), as well as essential fatty acids (fish and flax seed oils), may help provide additional calories to a vegetarian diet.

Vegetarianism does not greatly affect the fundamentals of optimal sports and performance nutrition. However, seeking advice from a dietitian may be beneficial in crafting an ideal performance nutrition plan.

Protein and Vegetarian Diets

Amino acids are the building blocks of protein. If a food contains the right combination of essential amino acids, it is called a *complete protein*. All animal-derived proteins and soy are complete. The remaining plant sources of protein contain many, but not all, of the essential amino acids and thus are considered *incomplete proteins*.

Previously, it had been suggested that vegetarians combine different plant foods at individual meals to ensure that all essential amino acids were provided at the same time. However, the American Dietetic Association has since stated that combining plant sources of protein meal by meal to meet

Table 1 Vegetarian Diets

Type of Vegetarian Diet	*Diet Description*
Fruitarian	Raw, dried, or cooked fruits, nuts, seeds, honey, and vegetable oils
Macrobiotic	Excludes all animal foods, dairy products, and eggs Uses only unprocessed, unrefined natural and organic cereals and grains Miso and seaweed are used as condiments
Vegan	Excludes all animal foods, dairy products, and eggs The vegan philosophy also excludes all animal products, including honey, gelatin, silk, wool, leather, and animal-derived food additives
Lacto-vegetarian	Excludes all animal foods and eggs Does include dairy products
Lacto-ovo-vegetarian	Excludes all animal foods Does include dairy products and eggs
Semivegetarian	Usually excludes red meat However, may include poultry, fish, eggs, and dairy products

the body's requirement for essential amino acids is unnecessary. Thus, as long as a variety of plant proteins are eaten throughout the day, adequate amino acids will be obtained.

A favorable eating regimen for vegetarian athletes is to ensure that protein-rich foods are included at each meal. Many athletes have limited time for meal preparation, particularly at lunch. Convenient and portable protein alternatives include ready-prepared beans (hummus, baked beans, and bean salad), nut and seed spreads (peanut butter and tahini), and ready-made luncheon meals made from soy or wheat gluten.

Along with including adequate protein, it is also crucial to obtain adequate calories so that protein is not used as an energy source. Athletes often have the misconception that the protein they consume is the only nutrient that is responsible for building more muscle. Actually, it is consuming enough calories that preserve protein for muscle repair and growth. Excess protein does not provide any advantage, and special protein supplements are generally not necessary. In summary, an athlete needs adequate protein, calories, and, most important, enough calories to spare, or make available, protein for growth and repair of tissues.

Meeting Vitamin and Mineral Needs

Athletes who are vegetarians have to include vegetarian alternatives in their diet that supplement certain vitamins and minerals that are commonly found in animal-based foods, such as vitamin D, riboflavin, vitamin B_{12}, iron, calcium, and zinc.

Vitamin D is important for bone health. Athletes need to ensure that they get adequate vitamin D from sun exposure and/or through fortified foods or supplements. Cow's milk, certain soy milks, and many breakfast cereals are fortified with vitamin D.

Riboflavin is low in vegetarian diets that do not include dairy products. It is an essential vitamin for the production of energy and thus important for athletes. Plant sources of riboflavin include fortified whole grains, soybeans, dark green leafy vegetables, avocados, nuts, and sea vegetables.

Vitamin B_{12} is needed for the production of normal red blood cells. Its deficiency may result in pernicious anemia and associated dementia. B_{12} is only found in animal products. The semivegetarian will obtain adequate B_{12} if fish and dairy products are consumed. The vegan will need to obtain B_{12}

through a supplement, nutritional yeast, fortified grains, or soymilk.

Calcium is essential for all athletes for optimal bone health. Vegetarians who do not include dairy products in their diet need to include calcium sources from plants or supplements. Athletes with low dietary calcium intake may have increased risk of bone fractures and stress fractures. Plant-based sources of calcium include kale, bok choy, turnip greens, and Chinese cabbage.

All athletes, especially female athletes, are at risk for iron deficiency. Iron plays a critical function in transporting oxygen throughout the body. There is also loss of iron due to heavy training. The absorption of iron from animal-derived foods is much higher than from plant sources. However, vitamin C significantly improves iron absorption from nonanimal sources. A diet rich in fruits and vegetables provides adequate vitamin C. Cooking in cast iron pots may also increase the iron content of certain foods. Iron-fortified breakfast cereals, spinach, beans, molasses, whole-grain products, textured vegetable protein, and some dried fruits (dried apricots, prunes, and raisins) are also good sources of iron.

In summary, with proper planning, athletes can choose a vegetarian diet that meets nutrient needs for athletic performance as well as for optimal health.

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See also Dietitian/Sports Nutritionist; Eating Disorders; Female Athlete Triad; Nutrition and Hydration

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Volkmann Contracture

Volkmann contracture, also known as *Volkmann ischemic contracture,* is a permanent flexion contracture of the hand at the wrist, resulting in a clawlike deformity of the hand and fingers. It may affect a single finger or the flexor muscles of the entire forearm. It may result from injury to brachial artery and is usually associated with supracondylar fracture of humerus, sometimes consequent to a high-impact fall as in skateboarding or other sports. It can also result from an intense twist of the upper arm, falling on an outstretched hand, or severe contraction of muscles. Baseball pitchers and other athletes who participate in throwing sports such as javelin and discus are vulnerable to this condition.

Classification

Ischemia is defined as cell death due to lack of blood supply. The intensity of injury depends on the type of cell and its energy requirements.

Ischemic injuries are classified in various ways. One is according to the severity of involvement:

Grade I: Ischemia

Grade II: Ischemic contracture

Grade III: Ischemic contracture associated with nerve involvement

They may also be classified according to the structures involved:

Type I: Contracture involving forearm muscles with intrinsic muscles intact

Type II: Contracture involving forearm muscles associated with paralysis of intrinsic muscles

Type III: Contracture involving forearm muscles as well as intrinsic muscles

Type IV: Mixed type

Tsuge's classification comprises three types, according to the extent and the muscle groups involved.

Mild: It is characterized by flexion contracture of two or three fingers with minimal loss of sensation.

Moderate: The thumb gets stuck in the palm, and all fingers are flexed; the wrist may be flexed with associated loss of sensation.

Severe: All muscles in the forearm, including both the flexors and extensors of the wrist and fingers, are involved.

Anatomy

The brachial artery branches into the radial and ulnar arteries. The radial artery is superficially positioned, whereas the ulnar artery is deeply placed, passing deep into the pronator teres muscles. The ulnar artery gives rise to the common interosseous artery, which immediately divides into the anterior and posterior interosseous branches. The anterior interosseous artery provides blood supply to the flexors of the forearm and hand.

Causes

Ischemic contracture may be caused by the following:

- Fracture
- Compartmental syndrome
- Tight bandages
- Arterial embolus
- Arterial insufficiency
- Improper use of a tourniquet
- Improper use of a plaster cast

Volkmann contracture occurs when there is insufficient blood supply (ischemia) to the forearm and is the end result of an untreated or relatively inadequately decompressed compartment syndrome in which ischemic necrosis of muscles has developed. The key factor in all cases of ischemic contracture is reduction in compartment size or increase in the content of a closed, uncompromising osteofascial compartment, which is enough to cause occlusion of small vessels.

The blockade immediately results in ischemia of the nerve and muscle. If the pressure is not relieved in time, it may result in damage to muscle contracture and nerves.

Decrease in the compartment size can be attributed to the following causes:

- Constrictive casts and dressings
- Persistent localized external pressure
- Injuries due to heat
- Burn Escher
- Plastic surgery of facial defects

This can also be attributed to an increase in compartment content resulting from hemorrhage, bleeding diathesis, or anticoagulation.

Diagnosis

The hallmark symptom of Volkmann contracture is pain that does not improve with rest or nonsedative analgesics. It will continue to get worse as time passes, and if the pressure is allowed to persist, there will be decreased sensation and weakness.

Besides pain, symptoms include pallor, pulselessness, paresthesias (numbness), and paralysis. Aggravation of pain on passive stretch is the most reliable finding on physical examination. Other symptoms include decreased sensation, weakness, and induration of the forearm. Pulselessness and paralysis are late symptoms. The forearm may show swelling and is also shiny. There is a typical flexion contracture of the wrist along with clawing of the fingers.

An absolute diagnosis is made based on direct measurement of the compartment pressure. It is done by inserting a needle into the compartment that is attached to a pressure meter. When the pressure is above 45 millimeters of mercury (mmHg) or when it is within 30 mmHg of the diastolic pressure, a diagnosis of compartment syndrome is made. This is the general test to diagnose compartment syndrome.

Treatment

Early recognition and timely treatment of imminent Volkmann ischemia decrease the presentation and severity of late contracture and hand dysfunction. Ideal treatment requires a thorough examination of the extent of damage of the ischemia, followed by conservative therapy or operation.

Management presents considerable challenges. The success in achieving a potentially functional and aesthetically satisfactory result is greatest in the acute phase. A physician should be immediately consulted in case of an injury to the elbow or forearm and if swelling is also present.

Nonsurgical Treatment

If there is a forearm or elbow fracture, a proper initial splinting of the hand in functional position should be performed; the area must be kept still, and the arm should be raised above the level of the heart. This helps in preventing further injury and excessive swelling. When the extent of injury is determined, conservative treatment techniques such as rest and ice should be started to help decrease the swelling. Pain relief and anti-inflammatory medicines may be prescribed. Casts and surgery also may be indicated, depending on the injury. Bed rest or use of a protective device (a knee brace or wrist guard) is usually advised. Physiotherapy may also be of help in rehabilitation. Early mobilization, range-of-motion exercises, followed by stretching and strengthening exercises are part of rehabilitation.

Surgery

The best treatment is early surgical intervention to release the pressure in the forearm in order to prevent permanent injury to muscles and nerves. Reconstructive surgery to lengthen and sometimes transfer muscles may restore some hand function.

Muscle sliding is considered the most effective method. It results in the best preservation of resting length of muscle.

Other methods include the following:

- Tendon lengthening
- Neurolysis
- Scar excision
- Tendon lengthening
- Tendon transpositions
- Nerve grafting

Stage 1 Contracture

Muscle-sliding operation usually results in complete recovery. It consists of median nerve neurolysis and removal of necrotic debris. For isolated muscle injuries, tendon lengthening is recommended.

Stage 2 Contracture

Transposition of flexor tendons has an equal effect to muscle-sliding operation. It is an imperative procedure that helps in the prevention as well as control of imbalance deformity, its indication depending on the personal as well as professional profiles of the individual patient. A tendon transfer procedure alleviates the suffering from functional impairment and provides a far better alternative to permanent external splints. This is usually a secondary procedure for replacing function, which is done after evaluation of the functional motor loss.

Stage 3 Contracture

The primary treatment option is muscle-sliding operation. Some secondary procedures such as tendon transpositions and nerve grafts are often necessary.

Stage 4 Ischemic Contracture

Muscle-sliding operations may help in improving deficiency in extension; however, wrist arthrodesis is of great help. The aim of arthrodesis is to achieve a relatively painfree wrist by eliminating movement. In this procedure, the bones are fixed. This procedure is more beneficial for young, active patients or middle-aged patients but not for elderly patients. Extensor tendon transpositions may be of benefit.

Long-Term Prognosis

Prognosis is variable and depends on the severity of the disease and the stage at which intervention is made. If the pressure is released earlier by surgery, before the onset of any permanent damage, then the prognosis is excellent. High compartment pressure for a longer period of time can result in permanent nerve damage. Cubitus varus and loss of radial pulse are the other complications reported.

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See also Elbow and Forearm Injuries; Elbow and Forearm Injuries, Surgery for; Elbow Fracture; Forearm Fracture

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Volleyball, Injuries in

Volleyball is the sport with the highest rate of jumping during practice and competition. Jumping seems to be the riskiest activity in volleyball because the majority of injuries are associated with jumping and landing. Defense is associated with a small number of injuries, while serving, passing, and setting are associated with even fewer injuries.

Epidemiologic studies of volleyball injuries have identified some of the risks of injury in the sport. The highest rate of injury in volleyball is associated with blocking, followed by spiking. These are also the two sport-specific activities that require a jump with every repetition.

Injury rates during competition have been evaluated. An injury is defined as "any condition causing the athlete to present to the medical staff during a tournament." In high-level play, a rate of injury between 1 per 25 hours and 1 per 50 hours is common. Injuries in American intercollegiate play have also been studied. "Any condition that resulted in missing a practice or match" is how an American intercollegiate group defines injury. Each practice or match was counted as one exposure. The rate of injury was about 4 per 1,000 athlete exposures in women's intercollegiate training and competition. This ranked volleyball second to softball for the lowest injury rate among 15 intercollegiate sports. Playing on a softer surface, such as sand, also seems to decrease the risk of injury.

Ankle Sprains

In volleyball, 15% to 60% of recorded injuries are ankle sprains. Ankle injuries are almost always associated with landing from blocking or spiking in the front court. The most common mechanism of injury occurs when the blocking player lands on an opposing spiker's foot that has come underneath the net and across the center line in the "conflict zone." The rules of volleyball allow a player's foot to cross this line beneath the net as long as some portion of the foot remains in contact with it. It often results in an inversion injury, where the ankle rolls outward. The ligaments on the outside, or lateral side, of the ankle are injured.

An ankle brace or orthosis is often recommended while actively rehabilitating, as it decreases the reinjury risk. Stirrup-style braces, particularly pneumatic-type orthoses such as the Aircast® brand, have been shown to decrease injury risk fourfold. The risk of reinjury is greatest during the first year after an initial injury, so it is recommended that braces be worn for a year after an ankle sprain. Braces have not been shown to decrease risk of injury in ankles that have not been previously sprained.

It may be possible to prevent a significant number of ankle sprains with a fairly simple prophylactic program. First, advise all players not to allow any part of their foot to touch the center line during practice. Second, identify "problem attackers." These are players who jump forward (doing a broad jump) when spiking the ball. These players should be coached to take longer last-approach steps and jump straight upward instead of out. A twofold decrease in ankle sprains may be anticipated. It should be easy to convince players that this is a good idea, because this technique actually results in a higher vertical jump.

Patellar Tendinitis (Tendinosis)

Patellar tendinosis (*jumper's knee*) is by far the most frequent overuse injury in volleyball. It is probably so common because of the high frequency of jumping inherent in the sport. Patellar tendinosis has been found to be more common in players who play more than four times weekly and are 20 to 25 years old. Players who have been in the sport for 2 to 5 years are also more likely to have symptoms. Plyometric training has *not* been associated with patellar tendinitis in these elite players. Most players with this condition have pain at the bottom part of the kneecap.

It may be possible to identify players who are at increased risk for patellar tendinosis. Those who can generate the greatest amount of power during jumping have been found to be at greater risk. These are also the players with the highest vertical jumps. Perhaps, they may not need as much jump training as their teammates. Deeper knee flexion at takeoff for jumping may also place players at greater risk. Coaching attention to proper jumping technique might help these players avoid injury.

Patellar tendinosis can usually be managed conservatively with ice, short-term anti-inflammatory medication, and alterations in training activity. Closed-chain eccentric strengthening of the quadriceps muscle can result in stronger fibers in the patellar tendon. An example of this sort of exercise would be leg presses where the athlete "works the negative." These exercises should be used to rehabilitate this condition.

Shoulder Tendinitis (Tendinosis)

The most common shoulder injuries in volleyball players are rotator cuff and biceps tendinosis as a result of overuse. They account for 8% to 20% of injuries in volleyball. Repetitively striking the ball overhead places a cumulative stress on the shoulder. Striking the ball at the highest point in the arm swing may place the shoulder at particular risk in this sport. These forces predispose the shoulder tendons to impingement with spiking and overhead serving. The tendons get impinged between the head of the humerus, or arm bone, and the acromion process, which sits above the shoulder.

A player who has shoulder pain and/or weakness should be evaluated by a physician, athletic trainer, or physical therapist. Sometimes, the entire shoulder girdle (including the shoulder blade) moves in an abnormal pattern. A rehabilitation program will often be prescribed. Abnormal shoulder blade movement should be addressed first. This usually involves shoulder retraction exercises. Then, rotator cuff exercises will help stabilize the ball in the socket.

Suprascapular Nerve Injury: A Volleyball-Specific Injury?

An unusual condition that may be present in up to one third of elite volleyball players is suprascapular nerve compression. Several factors may be involved with this problem, but the nerve is usually compressed by the bone of the shoulder blade near where it innervates the infraspinatus muscle. This is the muscle that externally rotates the shoulder. So players typically have isolated weakness of external rotation when a trainer evaluates their shoulder strength. Interestingly, the majority of the players with this condition do *not* have shoulder pain.

Players with this condition who have no pain probably do not require further evaluation or treatment. Findings of isolated external rotation weakness and infraspinatus atrophy should be noted on preparticipation physical exam for future reference, in case the player develops symptoms. In those with significant symptoms, such as shoulder pain, magnetic resonance imaging (MRI) may be helpful if surgery is being considered, because up to two thirds of affected individuals may have an abnormality called a ganglion cyst compressing the nerve.

Other Injuries

Volleyball players often suffer relatively minor hand or back injuries. These injuries are common yet rarely result in time missed from the sport. Sprain of the outside ligament of the thumb (metacarpal-phalangeal radial collateral ligament) is the most frequent hand injury seen in volleyball players. It often occurs with blocking and may require splinting or taping.

Low back injuries account for up to 14% of volleyball injuries. In teenage athletes, back pain should be evaluated by a physician, because back pain is unusual in this age-group and almost always occurs secondary to a condition that may respond to treatment. One such condition is spondylolysis, which is essentially a stress fracture of the low back. Athletes who have pain when they bend backward with their lower back (lumbar extension) should be evaluated by a sports medicine physician. This may occur in hitters, when they must repeatedly reach back behind their heads to contact the ball.

Severe knee injuries requiring surgery on the anterior cruciate ligament (ACL) are also rare, but these injuries seem to be more common in female players. A good way to evaluate female athletes who may be at risk for this injury is to observe players as they land after jumping off of a box. Those whose knees come together (into valgus) and touch on landing—"kissing knees"—should be considered for a program of exercises to prevent ACL injury.

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See also Ankle Sprain; Musculoskeletal Tests, Shoulder; Patellar Tendinitis; Shoulder Injuries; Shoulder Injuries, Surgery for; Thumb Sprain

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W

Warts (Verrucae)

Warts, or *verrucae,* are common skin findings that are often considered benign. However, in the athletic population they have the potential to cause significant pain and, thereby, impair performance. Although warts are found in every age-group, children and young adults are the most commonly affected, and athletes are at particular risk.

Human papillomavirus (HPV) is a virus that infects the skin and mucous membranes. There are more than 150 different types of HPV that cause warts in various areas of the body. Recently, several types of HPV have received additional attention because of their association with cervical cancer. The HPV vaccine is aimed at minimizing the spread of subtypes 16 and 18. The vast majority of HPV infect the skin and cause cutaneous warts. These types of HPV have virtually no potential to cause cancer.

Transmission of HPV occurs when the virus comes into contact with areas of damaged, even minimally damaged, skin. Transmission can be skin to skin or skin to fomite, such as shower room floors. Participation in sports can cause trauma to the skin, particularly to the feet and hands. In addition, the shared use of shower facilities and weight training equipment introduces multiple potential sources of exposure to HPV.

It is difficult to know exactly when an HPV infection occurs, because there is a lag time between exposure to the virus and the appearance of the resultant warts. The viruses commonly have an incubation period of between 1 and 6 months. Once individuals are infected, they risk passing this infection to other areas of their own skin through activities that cause minor skin trauma, such as shaving or scratching. Most subtypes of HPV cause specific types of warts that have predilections for certain areas of the body.

Symptoms

Two types of warts that frequently affect athletes are common warts and plantar warts. Common warts make up approximately 70% of cutaneous warts. They can be found anywhere on the body, but these most frequently affect the backs of hands and fingers. In children, these warts often appear on the face and neck. These warts are often described as "irregularly surfaced domed lesions."

One study looked at the acquisition of new common hand warts in runners and members of the crew team at a university. Rowers experienced hand trauma through weight training and rowing. Runners, on the other hand, experienced hand trauma from weight lifting alone. The study noted a significant increase in new common hand warts in crew team members compared with track team members. The authors postulated that trauma to wet, macerated hands made crew team members more susceptible to HPV and the resultant common warts.

Plantar warts are found on the sole of the foot and often cluster in the areas that bear significant pressure. The ball of the foot and the heel are the two most commonly affected sites. Because of their location, plantar warts can become callused and appear to grow into the foot. These warts are often found in small groups and can produce significant pain during weight bearing. Athletes with plantar warts may feel the sensation of having a pebble in their shoe while running or walking. Several factors predispose athletes to plantar warts, including communal showers, excessive perspiration, and repetitive microtrauma to the foot.

It is important to note that plantar warts can cause symptoms similar to stress fractures; therefore, plantar warts must not be overlooked when investigating plantar foot pain. A case report describes a 24-year-old female tennis player who was forced to stop play in the middle of a tennis match. She had tenderness over the ball of her foot, and it was suspected that she had a stress fracture. Following 2 weeks of rest, she returned to competition, and again the pain returned. Notably, she had calluses over the painful area of her foot. These calluses were pared down, exposing multiple dark spots (the "seeds" commonly found in plantar warts). Her plantar warts were treated, and she subsequently returned to play.

This situation illustrates how debilitating plantar warts can be for an athlete and the need to include plantar warts in the differential diagnosis for foot pain. Part of the difficulty in diagnosing plantar warts is that they are often covered with a callus. Once the callus is removed, plantar warts have a characteristic appearance: multiple black speckles, which are actually small blood vessels. These small blood vessels are the hallmark of plantar warts and differentiate them from other skin findings.

Treatment

There are several options available for the treatment of both common and plantar warts. Treatment can be broken down into three categories: (1) observation, (2) mechanical destruction, and (3) stimulation of the patient's immune system. Given the fact that cutaneous warts are caused by viruses, the immune system can potentially eradicate the viruses and the resulting warts. Warts affect patients with intact and impaired immune systems alike. However, individuals with impaired immune systems may never be able to mount an immune response significant enough to fight HPV.

Most warts in a healthy patient will resolve spontaneously (without intervention) over months or years. One study demonstrated the spontaneous resolution of two thirds of warts over 2 years. However, this process may take longer and be less successful than interventional measures. The longer the warts remain, the greater the potential for spread to different areas of the skin and to other people. Furthermore, the spread of warts may result in larger or more numerous warts, which may be more difficult to eventually remove.

Although most warts will resolve without intervention, the option of observation is much less desirable for athletes whose performance is impaired due to warts. These individuals may be more appropriate candidates for mechanical destruction. Mechanical destruction can be accomplished through a variety of measures. The most common types of mechanical destruction include topical acids, freezing, and curetting. However, it is important to note that destructive measures, particularly curetting, have the potential to leave a scar. Such scars, especially in the case of plantar warts, can be painful and can potentially inhibit the athlete's ability to run or even bear weight on the affected foot. Therefore, athletes must be cautious with more aggressive means of wart destruction.

Topical acids are effective, safe if properly used, and available over the counter. Salicylic acid is a common preparation often used as a first-line interventional treatment for both common and plantar warts. However, instructions for application can be complex and, thus, decrease patient compliance with treatment. To maximize the efficacy of salicylic acid, a regimen that includes daily soaking, debridement with an emery board, topical application of the acid, and occlusion with duct tape should be followed. This stepwise treatment should be repeated every 24 hours. Several studies have demonstrated that topical acids are more effective and faster at eliminating warts than simple observation (no intervention).

Freezing, or cryotherapy, involves the use of liquid nitrogen or nitrous oxide to destroy warts. The wart is frozen using a cryogun until the entire wart and up to 2 millimeters (mm) of the surrounding tissue turn white. A second freeze after thawing makes this method more effective. Following the freeze, the affected area will blister and then gradually slough and heal over the next few weeks. The freeze destroys the wart but also stimulates the immune system that aids in the destruction of any remaining HPV. Although much less complex than topical therapy, this method has the potential to cause blistering and pain, particularly in the case of plantar warts. While in training, athletes must decide whether the functional impairment from their warts is severe enough to warrant the potential complications of freezing.

Occlusion with duct tape alone has been used by many practitioners and has been the subject of several studies. Although the exact mechanism of treatment with duct tape is not known, several theories have been proposed, including suffocation of warts, immune response stimulation, and mechanical debridement. In 2002, a study compared the efficacy of cryotherapy with that of duct tape occlusion. The results showed that duct tape occlusive therapy was significantly superior to cryotherapy in resolving common warts. However, two other studies have questioned the efficacy of duct tape occlusion as a successful therapeutic intervention. These studies demonstrated no significant differences in the resolution of warts when compared with placebo treatments such as corn pads or moleskin coverings. Though they showed a nonsignificant initial resolution of the wart, return of the wart was equally demonstrated. Questions still remain as to whether differences in the type of duct tape, silver versus transparent, could account for the divergent outcomes of these studies.

There are also various methods that have been used to stimulate the immune system to facilitate the destruction of HPV and the resulting warts. These methods are directed at enhancing the immune response both locally and systemically. Injection of *Candida* into the base of a wart is one way to generate a local immune response. The body's natural response to the fungus will supply the injected region with host cells that target the *Candida* as well as the viruses causing the wart. Similarly, topical agents such as imiquimod cream and diphenylcyclopropenone generate a local inflammatory response that enhances virus destruction. Interestingly, the H2 antagonist cimetidine (a medicine frequently used for the treatment of heartburn) has been used in an attempt to stimulate human immune cells to facilitate the regression of warts. Although early uncontrolled studies supported the efficacy of high-dose cimetidine, more rigorous double-blind controlled trials have contradicted these findings.

Conclusion

Warts are a common skin finding that have the potential to cause pain and impair performance in athletes. Although there are several methods for treating warts, preventive measures can help athletes avoid an HPV infection. Athletes who use communal showers should wear sandals and avoid direct contact with shower floors. Athletes may consider the use of drying agents to avoid moisture, which, by leading to maceration of the skin, increases the likelihood of infection with HPV. If athletes do develop warts, they should take into account the potential for side effects when selecting a treatment modality.

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See also Dermatology in Sports; Fungal Skin Infections and Parasitic Infestations; Skin Disorders Affecting Sports Participation

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WEIGHT GAIN FOR SPORTS

Many sports require an athlete to lose or maintain weight to optimize performance. Conversely, some sports and sports positions require weight gain for a greater competitive advantage. In some cases, the extra pounds can mean the difference between winning and losing. This entry describes how athletes may safely gain weight to achieve a competitive advantage.

Gaining weight is important for those who are underweight or who require greater strength. Gaining weight may also increase energy and endurance. Endurance is a person's ability to cope with intense and frequent exercise, such as distance running, swimming, or biking over long time periods or distances. Weight gain may also help an athlete to build muscle and increase strength. This strength may offer some athletes a protective advantage in sports such as football or hockey. The optimal time for gaining weight is during the off-season or at the beginning of the season.

Gaining weight may not be easy. In fact, often it is harder than losing weight, as athletes may use energy faster than they consume it. The question for the athlete is how to gain weight while still maintaining a healthful diet. In short, weight gain requires excess calorie intake. Each pound of weight gain requires 3,500 additional calories (cal; 1 cal = 4.2 joules). This is achievable by incorporating an extra 500 cal/day into the diet. If an athlete consumes an additional 500 cal/day for 1 week, then 1 pound (lb; 1 lb = 0.45 kilograms) of weight gain should be the outcome. Ideally, this should be combined with a resistance training program. The goal is not just to increase weight but also to increase lean muscle mass.

A combination of protein, carbohydrate, and fat is optimal for weight gain. The percentages of each of these macronutrients are approximately as follows: carbohydrate at 50% to 65%, protein at 15% to 20%, and fat at 25% to 30%. If these percentages are viewed as grams per day, the following is recommended: carbohydrate at 5 to 10 grams per kilogram per day (g kg^{-1} day^{-1}), protein at 1.0 to 1.7 g kg^{-1} day^{-1}, and fat at approximately 1 g kg^{-1} day^{-1}.

Maintaining a healthful diet of whole grains, fruits and vegetables, lean protein, and heart-healthful fats will help optimize performance. Weight gain, just like weight loss, takes time. The overall goal is to gain about 0.5 to 1 lb/week. Athletes trying to gain weight should consume three meals and two or three snacks each day. Skipping meals such as breakfast may make it more difficult to obtain the necessary calories needed to gain weight.

Weight Gain Methods

Many athletes think that additional calories should be obtained only from protein. Studies show that consuming excess protein (defined as more than 1.8 g kg^{-1} day^{-1}) may increase the oxidation of excess amino acids. Furthermore, excess protein may be converted to fat. Thus, a diet with too much protein has no advantage for muscle gain, when compared with a lower protein intake that is coupled with resistance training.

The speed at which weight gain occurs may depend on the athlete's genetic makeup, the calories consumed in excess of metabolic and training needs, the number of rest and recovery days per week, and the training program itself. Weight gain is achieved by ensuring that each meal and snack are made up of healthful, higher-calorie foods. Beverages are one easy way to increase calories. For example, instead of water, the athlete may add juice, milk, milk shakes, and instant breakfast drinks to meals or snacks. It is also important to snack regularly and carry healthful snacks each day to encourage snacking. Such snacks may include dried fruit, yogurt, cheese and crackers, nuts and peanuts, bran or fruit muffins, and multigrain bagels with cream cheese or nut butters.

Athletes may think that the need for extra calories gives them the right to eat whatever they want, but this may be detrimental to both performance and overall health. Substitutes may be found for many food items. For example, instead of using butter, canola or olive oil may be substituted. Mayonnaise may be replaced with avocado spread. Natural peanut butter may be spread on bagels, crackers, or bread instead of butter or cream cheese. Eating healthful foods in abundance is how an athlete gains weight safely and effectively. There is no need to add calories with fast food or junk food when calories are easily added by making favorable choices at meal and snack times.

Many athletes wonder whether protein supplements are helpful when trying to bulk up. These supplements are often marketed as ways to gain extra muscle quickly. However, the main reason why protein supplements help an athlete gain muscle is that they contain extra calories. Also, contrary to what some people believe, most athletes need only a small amount of extra protein to gain weight and muscle mass. The protein in the supplements is often too high. Caloric and protein needs may be met by eating a variety of healthy foods each day. If extra calories are needed, readily available weight gain drinks such as Ensure or Boost contain the extra calories and are marketed specifically for weight gain.

There are also unhealthful ways of gaining weight. A few of these are human growth hormone (HGH), anabolic steroids, and insulin. HGH use may increase the risk of diabetes, hypertension, joint pain, and possibly colon cancer. Anabolic steroids have been linked to many health problems, including breast growth and shrinking of testicles in men, voice deepening and growth of body hair in women, heart problems, liver disease, and aggressive behavior. Insulin is sometimes used in bodybuilding to increase the bulk of muscles. Insulin is a natural hormone secreted by the pancreas in response to high sugar levels. Its main use is to regulate sugar levels in the body. However, if one is not diabetic, taking insulin unnecessarily may cause the pancreas to stop producing insulin naturally, which might lead to diabetes.

Weight Gain Tips

Weight gain requires that an athlete eat consistently and not skip meals or snacks. Portions should be larger than normal, and calorically dense foods should be encouraged. Higher-calorie meals may also result from reading food labels to determine which foods have more calories than an equally palatable counterpart. For example, cranberry apple juice has more calories than does orange juice (170 vs. 110 cal/8 fluid ounces [oz; 1 oz = 29.57 milliliters]), granola has more calories than do Cheerios (700 vs. 100 cal/cup), and corn has more calories than do green beans (140 vs. 40 cal/cup).

In terms of individual food groups, the following guidelines may be helpful. Choose heavy breads such as honey bran, rye, and pumpernickel instead of lighter breads such as white bread. Choose cereals such as granola, instead of rice puffs or corn flakes. The caloric value of cereals may also be increased by adding nuts, raisins, and other dried fruits. When choosing fruits, bananas, pineapple, mangos, raisins, dates, and other dried fruits have more calories per serving than do watery fruits, such as watermelon, grapefruit, apples, and peaches. Starchy or sugary vegetables, such as corn, carrots, and peas, have more calories per serving than do less starchy vegetables, such as green beans, broccoli, and summer squash. Lentils, lima beans, chili beans, and other beans are also high in calories. These foods are good choices, because they also provide both carbohydrates and protein. In terms of other protein foods such as meat, fish, and poultry, certain types and cuts are higher in calories. Dark meat of poultry, fatty fish such as salmon and trout, and some cuts of lean red meat are high in calories, including round or sirloin steak, ground round, fresh or boiled ham, or center-cut loin chops.

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See also Dietitian/Sports Nutritionist; Lean Body Weight Assessment; Nutrition and Hydration; Obesity; Weight Loss for Sports

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Weight Lifting, Injuries in

Weight lifting is performed by itself as a competitive sport and by athletes in other sports as part of training programs to increase muscle strength, endurance, and power. The high amount of resistance and repetitive movements in weight lifting can cause both acute and chronic injuries to muscle, tendon, and bone. The body parts most commonly injured by weight lifting include the shoulders, knees, and lumbar spine. Although serious injuries can occur, most weight lifting injuries are relatively minor.

General guidelines should be followed to decrease the risk of injury from weight lifting. As in any other sport, athletes should perform a proper warm-up before weight lifting. This can

Personal trainer demonstrates proper technique for squat exercise with barbells.

Source: David H. Lewis/iStockphoto.

include stretching, cardiovascular exercises, or performing several repetitions of lifting light weights with controlled movements.

Proper technique is also critical to minimize the risk of injury. A spotter should be used when appropriate. Young athletes should always be under direct supervision when lifting weights.

To avoid injuries from overtraining, adequate time should be given for muscle recovery. Performance-enhancing substances should be avoided. Specific injuries and prevention techniques are discussed in the sections that follow.

Shoulder Injuries

The inherent instability of the glenohumeral joint combined with the high amount of weight used during exercises involving movements of the glenohumeral joint place soft tissues around the joint at risk of injury. Strains of the rotator cuff and deltoid muscles are common. Weight lifting exercises, such as front and lateral deltoid raises, and military presses that involve resisted overhead movements can place the athlete at risk for subacromial impingement.

In addition to the glenohumeral joint, the acromioclavicular joint is also stressed with repetitive overhead movements, dips, and bench press. Osteolysis of the distal clavicle joint is a relatively common condition in weight lifters.

Anterior shoulder structures, including the glenohumeral ligaments, are stressed during weight lifting exercises where the arm moves beyond the body in the coronal plane. This movement occurs when performing a bench press, behind-the-head latissimus pull-down, pec deck machine, and dumbbell chest fly through a full range of motion. A back squat is an example of a lower extremity exercise that can also stress the shoulder joint as it places the shoulder in excessive horizontal abduction and extension. Athletes with glenohumeral joint laxity are predisposed to injury with these exercises.

A rupture of the pectoralis major muscle is an example of a traumatic upper extremity injury that can occur while weight lifting. Although it is not a common injury, the injury classically occurs while performing a bench press. Rupture of the pectoralis major insertion requires surgical repair.

Shoulder Injury Prevention

Minor modifications to traditional weight lifting exercises can decrease the stresses on the shoulder joint that lead to the injuries discussed earlier. During the latissimus pull-down, the bar should always be lowered in front of, not behind, the head. A narrow grip during the latissimus pull-down and bench press will decrease stress on the anterior shoulder structures and acromioclavicular joint. Decreasing the range of motion with a bench press, cable fly, pec deck machine, and dumbbell chest fly so the arm stays anterior to the coronal plane of the body will also decrease stress on the anterior shoulder structures. When performing overhead movements, externally rotating the humerus will rotate the greater tuberosity and minimize the risk of subacromial impingement.

Maintaining proper muscle balance will also help decrease the risk of shoulder injury. Specifically, strengthening of the rotator cuff and scapulothoracic muscles is needed to avoid muscular imbalance, as most common weight lifting exercises strengthen the deltoid and anterior chest muscles.

Knee Injuries

Anterior knee pain is a common complaint of weight lifters. Anterior knee pain can be caused by strain or injury to any of several structures, including the patellar tendon and patellofemoral joint. Patellofemoral joint stresses are high during deep knee flexion in weight bearing, such as squatting, leg press, and lunges, especially when the exercise is performed beyond 90° of knee flexion. Knee extensions strengthen the quadriceps in a non–weight-bearing position. With this motion, the patellofemoral joint stresses increase as the knee extends beyond approximately 45°.

The menisci in the knee are also susceptible to injury during weight lifting. Acute and degenerative meniscal injuries can occur due to high loads on the tibiofemoral joint with the knee in a flexed position, such as during squats and lunges.

Knee Injury Prevention

Avoiding deep squats and lunges (limiting knee flexion to less than 90°) will minimize stress on the patellofemoral joint and meniscus. Non–weight-bearing knee extension exercises should be performed from 90° to 45° of knee flexion to minimize patellofemoral joint stress.

Lumbar Spine Injuries

Exercises that place excessive forces on the lumbar spine include squats and deadlifts. The most common injuries to the lumbar spine during weight lifting are muscle strains and stress injury or fracture to the pars intraarticularis (spondylolysis). Spondylolysis results from repeated hyperextension of the spine.

Athletes should maintain a neutral spine position whenever possible with all types of weight lifting exercises. Co-contraction of the multifidus with the deeper abdominal muscles (transverse abdominis, internal and external obliques) will stabilize the lumbar spine and avoid excessive forces from hyperflexion and hyperextension movements during weight lifting exercises. Excessive hyperextension during exercises such as military press, bench press, and squats should be avoided.

Special Considerations

Competitive Weight Lifting

Competitive weight lifting consists of power lifting and Olympic weight lifting. Competitive power lifts include deadlifts, squats, and bench press. Olympic weight lifts consist of the clean and jerk and the snatch. Athletes in these two competitive weight lifting sports want to reach as high a one-repetition maximum as possible and often lift weights three to five times their body weight. This requires the athlete to generate extremely large muscle forces and high joint torques.

Injuries to the lumbar spine and knees are the most common in Olympic weight lifting, whereas injuries to the lumbar spine and shoulder are the most common in power lifting. When performing a squat, power lifters position the bar lower on their back and lean their trunk more forward, resulting in less ankle dorsiflexion and a more posterior hip position, ultimately leading to less knee extension torque and less risk of knee injury. In contrast, when weight lifters perform the snatch, they are in a position of deep knee flexion, which increases stress on the knee joint. Although the low bar squat position used by power lifters results in less stress to the knee joint, it does increase stress on the anterior shoulder structures.

Youth and Weight Lifting

Weight lifting can be safe and beneficial for preadolescents and adolescents. An appropriately designed program will improve muscle strength and have general health benefits. It will not have any adverse effects on growth or lead to any medical risk in an otherwise healthy child. The increases in muscular strength seen in preadolescents are likely due to neural gains (changes in motor unit activation and recruitment) rather than due to muscle hypertrophy.

Free weights, elastic bands, exercise machines, and body weight are all various modes of resistance that can be used. Body weight resistance exercise is beneficial to emphasize proper technique and incorporate core strength. If exercise machines are used, they must be sized appropriately.

A weight training program for youth should emphasize proper technique, which requires appropriate supervision. A low to moderate resistance level should be used, with a higher number of repetitions (2–3 sets, 8–15 repetitions). The program can be performed two to three times per week.

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See also Core Strength; Resistance Training; Running a Strength Training and Conditioning Facility; Strength Training for the Female Athlete; Strength Training for the Young Athlete

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Weight Loss for Sports

Weight loss is a reduction of the total body weight. This reduction is due to a mean loss of fluid, body fat, or adipose tissue and/or lean mass—namely, bone mineral deposits, muscle, tendon, and other connective tissue. Weight loss can be unintentional or intentional. Unintentional weight loss refers to the involuntary loss of weight secondary to genetics, some medical conditions, activities, or medications that decrease body mass. Intentional weight loss refers to the voluntary loss of total body mass in an effort to improve fitness, health, and/or appearance. Intentional weight loss in sports refers to the intentional loss of total body mass in an effort to improve fitness or athletic performance and/or to meet a sport-specific weight requirement. Weight loss occurs when an individual is in a state of negative energy balance. When the human body is spending more energy in work and heat than it is gaining from food or other nutritional supplements, it will use the stored reserves of fat or muscle. Although weight loss may involve loss of fat, muscle, or fluid, weight loss for the purposes of maintaining health should aim to lose fat while conserving muscle and fluid.

Weight Loss Techniques

The most often recommended weight loss techniques are adjustments to eating patterns and increased physical activity. Other methods of losing weight include the use of drugs and supplements that decrease appetite, block fat absorption, increase metabolism, or reduce stomach volume. Finally, surgery may be used in case of morbid obesity.

Dieting

One of the aspects of energy balance that affects body weight is energy intake. An examination of the weight loss literature shows that changes in energy intake play a significant role in reducing body weight. The currently available scientific evidence appears to indicate that the macronutrient content of the diet will affect body weight only when there is also a reduction in the total energy intake.

Athletes usually require a greater caloric intake than nonathletes. The actual energy intake (number of calories) depends on the athlete's body composition, weight, height, age, stage of growth, and level of fitness as well as the intensity, frequency, and duration of exercise activity. Athletes need to eat enough to cover the energy costs of daily living, growth, building and repairing muscle tissue, and participating in sports. Athletes need to be informed that weight is not an accurate indicator of body fat or lean muscle mass and that body composition measurements can be more helpful.

When athletes regularly restrict energy intake to less than 1,500 kilocalories per day (kcal/day; 1 kcal = 4,184 joules) for women and less than 1,800 kcal/day for men, they are at increased risk of poor nutritional intake. This level of energy intake is too low to meet the nutritional needs of the body and fuel the body for exercise, especially if physical activity is high.

Commercial programs recommend various combinations of macronutrient compositions for weight loss, including high-fat, high-protein, and high- and low-carbohydrate diets. Despite the popularity of many of these dietary approaches, the optimal macronutrient composition of the diet for weight loss has not been determined. Despite the different potential mechanisms for how changes in protein intake may affect weight loss, evidence from clinical trials supporting optimal protein and carbohydrate intake for long-term weight loss and weight maintenance is lacking.

Exercise

Scientific evidence suggests that the combination of dietary modification and exercise is the most effective behavioral approach for weight loss, and the maintenance of exercise may be one of the best predictors of long-term weight maintenance. Despite the importance of exercise, there is little evidence that suggests that exercise alone produces magnitudes of weight loss that are similar to what can be achieved with dietary modification. Also, when examining the effect of exercise on body weight, it has been suggested that there may be "responders" and "nonresponders" to the same exercise intervention. In general, daily guidelines for exercise are 60 to 90 minutes to prevent weight gain and over 90 minutes to maintain weight loss.

Behavior Modification for Weight Loss

Behavior modification for weight loss means lifestyle changes to develop a long-term healthy eating plan and exercise program. There is evidence that including behavioral principles within a weight loss program improves long-term outcomes. Maintaining contact with participants long term improves long-term weight loss outcome, and this is considered an important component of behavioral weight loss programs. Another important component of behavioral weight loss programs is self-monitoring of eating and exercise behaviors. There is consistent evidence that individuals who self-monitor these behaviors are more successful at weight loss than those individuals who are inconsistent with self-monitoring. The use of portion control diets may also improve weight loss outcomes by minimizing choice and providing specific guidance to adults that precipitates weight loss.

Pharmacological Treatment

All current guidelines consider pharmacotherapy to be an adjunct to lifestyle modification interventions and limit its use to patients with obesity or overweight patients with additional comorbidities (e.g., hypertension, dyslipidemia, or Type 2 diabetes).

Despite the interest in the potential use of pharmacotherapy for the management of body weight, there are few drugs approved for this use, and their safety and effectiveness have not been established for use beyond 2 years. Most available weight loss medications approved by the FDA are appetite-suppressant medications. These include sibutramine, phentermine, phendimetrazine, and diethylpropion. Appetite-suppressant medications promote weight loss by decreasing appetite or increasing the feeling of being full. These medications make the patients feel less hungry by increasing one or more brain chemicals that affect mood and appetite. Phentermine and sibutramine are the most commonly prescribed appetite suppressants in the United States. *Amphetamines are a type of appetite suppressant. However, amphetamines are not recommended for use in the treatment of obesity due to their strong potential for abuse and dependence.*

Another category of medication used for weight loss is orlistat. This medication reduces the body's ability to absorb dietary fat by about one third. It does this by blocking the enzyme lipase, which is responsible for breaking down dietary fat. When fat is not broken down, the body cannot absorb it, so it is eliminated, and fewer calories are taken in.

All weight loss agents should be used only under the direct supervision of a physician.

Pathologic Strategies and Health Concerns

Pathologic weight loss strategies include any weight loss behaviors or actions that are potentially harmful to the athlete. These strategies include restrained eating, chronic dieting, bingeing and purging, skipping meals, fasting, excessive exercise, dehydration, and laxative, diuretic, and emetic abuse.

Nutritional Deficiencies

To lose weight, athletes frequently restrict food intake by skipping meals, eliminating food groups, fasting, or eating only one to three foods a day. Severe energy restriction is especially a problem for female athletes, and this pattern can lead to the female athlete triad (amenorrhea, eating disorder, and osteoporosis). Female athletes typically need less energy than male athletes due to their smaller body size. In addition, even female athletes who are not dieting frequently have energy and nutrient intakes that are below the recommended levels.

Disordered Eating

For some athletes, chronic dieting to maintain a low body weight can be the first step toward developing a clinical eating disorder such as anorexia nervosa or bulimia nervosa. Persistent dietary restriction can lead to binge and purge eating. Bingeing includes consuming large quantities of food at one time, followed by purging through practices such as self-induced vomiting; the use of emetics, laxatives, or diuretics; and excessive exercise. Bingeing and purging are extremely dangerous practices that can lead to clinical eating disorders, tooth decay, poor performance, dehydration, and even death due to fluid and electrolyte imbalances.

Dehydration and Laxative Abuse

Dehydration is a practice commonly used for rapid weight loss in athletes needing to "make weight." One way of doing this is by exercising intensely in hot environments while wearing vapor-impermeable suits. Also, some athletes combine this activity with fluid restriction and the use of diuretics, emetics, and laxatives. This practice is extremely dangerous and has resulted in several documented deaths.

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See also Dietitian/Sports Nutritionist; Lean Body Weight Assessment; Nutrition and Hydration; Obesity; Weight Gain for Sports

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Weight-Control Information Network: http://win.niddk.nih.gov/publications

Windsurfing, Injuries in

Windsurfing is a challenging and exhilarating aquatic sport that has gained worldwide appeal fairly quickly, including its introduction as an Olympic sport in 1984. There is something for everyone in this sport, whether you are a recreational amateur, Olympic competitor, or Professional Windsurfing Association champion. Exercise, excitement, thrill, and challenge are among the stimuli to participate, while trauma, injury, and overexposure to the elements represent the downside. Knowledge of the sport, proper equipment, and windsurfing skills help ensure that the positive aspects of windsurfing are enjoyed and the risks are avoided.

Windsurfing is an ingenious combination of Hawaiian-style wave surfing and the more accessible sport of wind sailing. The marriage of a one-person sailboard and a one-person sail by means of a universal (polyaxial) joint brought the intuitive burst to reality. Wave surfers are no longer limited to the few locations worldwide where the "perfect wave" might appear and impart massive kinetic power to propel a surfboard. Rather, one can now harness the more ubiquitous power of the wind to propel a sailor through the water and waves. The inception of the windsurfer was a "Eureka moment."

Basic Equipment

The sport of windsurfing requires a sailboard commonly referred to as a windsurfer and a rig consisting of sail, mast, and boom. The rig is attached to the sailboard by means of a universal joint that allows the rig to be tilted, pivoted, or flipped into various positions. The sailboard provides the flotation on which the sailor stands, sails, steers, and maneuvers through the water and waves. The rig supports the sail, which captures the wind power and allows the sailor to transfer it to the sailboard. Adjustments in the positions of the rig and sail provide the means by which to steer the board and finely balance the amount of wind power transferred to the board. A fin provides lateral resistance and lift to the board. Sail power and fin allow the windsurfer to hydroplane, making it the fastest sailing vessel on the water, capable of attaining speeds of over 50 miles (mi; 1 mi = 1.60 kilometers) per hour.

The booms may be aided by hand, or a harness may be worn to allow the sailor to hook into the straps attached to the booms. This permits the sailor to balance sail power against body weight, removing the burden from the arms and freeing the sailor to make fine adjustments to sail position. Foot straps are affixed to most sailboards, allowing the sailor to anchor his or her feet to the board and more efficiently transfer wind power to the board. Foot straps not only prevent the windsurfer from being thrown (catapulted) from the board but also provide a potential mechanism for injury to the lower extremities because they lock the feet in place and can thereby cause twisting injuries to the ankles and knees. Ancillary equipment includes gloves, booties, harness, wet suit, life jacket, and helmet.

The length and volume of windsurfers vary according to the ability of the sailor, the type of sailing intended, and the conditions of wind and water. Novice sailors and low wind conditions require larger boards for greater flotation and moderate-sized sails, which allow greater control. Slalom and freestyle sailing are accomplished on smaller boards, which are faster and more maneuverable but more difficult to sail. High wind days and wave sailing require that the smallest boards and sails be used. Sailors must carefully assess the wind velocity, water conditions, and local topography and their own sailing abilities prior to selecting the equipment used on any given day. Too small a board or rig on a low wind day may leave the sailor stalled or sunk (underpowered). Too large a board or rig on a high wind day may put the sailor in an uncontrollable situation, either blown off course or thrown about at the mercy of the wind and waves (overpowered).

What Can Go Wrong?

For the most part, windsurfing is a safe and enjoyable endeavor. Even an unsuccessful day of windsurfing is typically a “good day at the beach” with sun, water, waves, companionship, and recreation. Potential problems with equipment, weather conditions, or sailing ability may lead to injury. Medical studies estimate that the rate of injury to windsurfers is approximately 1.5 per year, with the majority of injuries being minor. These would include strains, sprains, contusions, or bruises, which rarely require medical attention. An ill-equipped novice sailor may develop hand blisters if improper gloves are worn or scrapes and scratches if no protective booties are worn. While

Windsurfer in Dingle Peninsula, County Kerry, in Ireland. Most of the injuries common to windsurfing are minor and include strains, sprains, contusions, or bruises.

Source: Ingmar Wesemann/iStockphoto.

learning to manipulate the sailboard and rig into correct positions, there is an intuitive inclination to force one's equipment into position rather than use simple physics and wind power to do the work. These undue efforts produce backaches, muscle strains, joint sprains, and contusions, which constitute the garden-variety problems that heal quickly. Beginners can avoid many of these struggles and injuries by taking lessons from certified instructors, consulting instruction manuals, or viewing the many excellent instructional videos that are available. *Windsurfing Magazine* and windsurf.com are good sources of information.

There are potentially serious, and frankly dangerous, situations that may lead to severe physical harm. Extreme overexposure to environmental elements can occur if a sailor is incapable of upwind sailing and consequently is blown downwind and away from the intended destination. Sailors have been stranded out at sea or even lost entirely. Equipment failure and major alterations in wind velocity or direction can produce similar results, blowing a sailor drastically off course. Prolonged exposure to the elements may lead to severe sunburn, dehydration, exhaustion, hypothermia, or drowning. These potential dangers underscore the importance of knowing your local conditions, the prevailing winds, the weather forecast, and equipment maintenance. Solo sailing is a hazard, and it is a windsurfing maxim to be with a "buddy sailor" and to know the whereabouts of rescue boats or vehicles. "Never leave your board" is another important maxim since it serves as your flotation device and may be kicked or paddled for long distances. Ancillary equipment such as a Coast Guard–approved life jacket, a wet suit, gloves, sunglasses, and booties help protect from exposure. Waterproof radios are expensive but may be crucial to the solo sailor who has ventured off course or become stranded. It is imperative to stay with your board, avoid solo sailing, and know the universal "sign of distress" to alert others to your plight. This involves sitting on your sailboard and raising both hands straight overhead and crisscrossing them back and forth.

Physical Injuries

Much of windsurfing's appeal is its overall safety. Being blown off course typically results in much paddling and walking rather than dramatic rescues. Similarly, most falls, collisions, or mishaps lead to splashy and refreshing immersions into the water, followed by uphauling or water starting to get back on course.

As a sailor progresses in his or her abilities, there is typically the urge to seek more challenge and greater speed and perform stylized turns, and wave jumping. Freestyle sailing involves phenomenal loops, rolls, and other aerial acrobatics. Higher speeds, crowded races, and advanced aerial maneuvers create the circumstances that may cause severe high-energy injuries. These injuries most frequently involve the lower extremities, affecting the knee, ankle, and foot. The lower extremity is placed at higher risk because of the foot straps that lock the foot onto the board. While the foot strap gives the sailor greater control over the board, the converse is unfortunately also true. Just as a ski bound to the foot of a skier can impart greater leverage and injury to the leg of a skier, the foot strap can impart greater leverage of the board and rig to the lower extremity of the sailor. If uncontrolled leverage due to a fall, aborted turn, or poor landing from a jump is transmitted to the vulnerable lower extremity, ligamentous tears may occur to the foot, ankle, or knee. Further leverage will cause complete rupture of ligaments or fracture of bone. Lower extremity injuries reported among windsurfers include midfoot sprains and complete disruption of the tarsal bones of the foot, known as Lisfranc fractures. The collateral ligaments of the ankle or knee may be disrupted, or the anterior cruciate ligament of the knee may be torn. Knee injuries of this severity are commonly associated with a "popping" sensation rapidly followed by pain, swelling, and difficulty bearing weight. Immediate emergency treatment involves *r*est, *i*ce, elastic *c*ompression, and *e*levation (RICE) followed by medical evaluation. Most sprains are partial tears and respond to rest, use of splints, and temporary use of a cane or crutches. Fractures, dislocations, or complete ligamentous disruption typically requires surgical treatment.

While most serious windsurfing injuries involve the lower extremity, other body parts are also at risk. The most common serious upper extremity injury is dislocation of the shoulder during high-velocity falls, catapults, or collision with other sailors. Chest wall contusions or rib fractures may result from collision with one's booms. Head, neck, and spinal injuries also have been reported and are typically associated with high-energy aerial acrobatics, collision with other sailors, or direct contact with the sea bottom. These catastrophic injuries may lead to concussions, skull fractures, vertebral fractures, spinal cord injuries, or death. Prevention, caution, and head protection are the keys to avoiding these catastrophic injuries. Windsurfers must follow sailing's "rules of the road," which determine who has the right of way on the water when conditions are crowded. Riders must know both their abilities and their limitations. Winds too strong, waves too high, and waters too crowded must signal caution. While helmets are not everyday requirements, they are an absolute must for high winds, crowded racing conditions, and freestyle sailing. Whenever in doubt, it is always prudent to decide on the side of caution.

Last, whether you are on home territory or on an exotic windsurfing vacation, it is important to do a little preparatory work researching your destination. Fortunately, most windsurfing destinations provide resources describing the local conditions, such as prevailing winds, water depths, rock or coral formations, and temperature extremes. Local flora and fauna may also provide potential hazards, such as sea urchins, needle fish, jellyfish, sharks, or marine bacteria, which may cause infection of scrapes or puncture wounds.

Peter P. Anas

See also Ankle Injuries; Bruised Ribs; Foot Injuries; Head Injuries; Rib Fracture and Contusions; Sunburn; Sunburn and Skin Cancers

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Women's Health, Effects of Exercise on

Cardiovascular disease (CVD) remains the leading cause of morbidity and premature mortality in women in the United States and most industrialized countries and, more recently, contributes to the significant disease burden in the developing nations. The prevalence of obesity and inactivity among Americans continues to rise. Exercise, for the physiologic reasons discussed below, has a beneficial effect in both preventing CVD among women and treating it once it occurs. Inactivity is also associated with multiple other cardiovascular risk factors, including obesity, diabetes, and hypertension. Furthermore, beyond its widely touted promotion of cardiovascular health among women, exercise has been shown to have multiple beneficial effects on other aspects of women's health. Among women, exercise has been shown to decrease the risk of colon and breast cancer, decrease the risk of osteoporosis, and boost cognitive and psychological well-being. In considering the myriad beneficial effects of exercise among women, it should be noted that these are independent of diet and weight loss.

Cardiovascular Adaptation to Exercise Training

Typical cardiovascular adaptations to regular aerobic physical training include lowered blood pressure and heart rate, mild increases in the dimensions of the heart cavity, augmentation of the amount of blood pumped by the heart, as well as increases in heart muscle mass. In addition to the structural changes that occur with training, changes in heart physiology also occur. These include an enhanced pumping and relaxation function of the right and left ventricles, the heart chambers that pump blood to the lungs and the aorta, as well as an increase in the amount of oxygen consumed by the body, known as the $\dot{V}O_2$max. $\dot{V}O_2$max is widely considered to be the gold standard metric for cardiovascular fitness.

While the majority of cardiovascular adaptations to training are similar between men and women, unique cardiovascular adaptations to exercise in women have been described. While both men and women exhibit increases in their heart chamber sizes and muscle mass, the body surface–adjusted increases in mass are not as substantial in women as in men. In addition, females exhibit lower $\dot{V}O_2$max compared with males, likely due to lower myocardial mass.

Additional physiologic differences between men and women may contribute to the improvement in $\dot{V}O_2$max observed with regular physical exercise. While the mechanism of increased $\dot{V}O_2$max in men appears largely due to increases in the volume of blood pumped by the heart, in women, the improvement appears to be related to the increased extraction of oxygen from muscle at the cellular level.

The Role of Exercise in the Reduction of Cardiovascular Risk Factors

Regular physical exercise is of great value in reducing established cardiovascular risk factors, including obesity, diabetes mellitus, and hypertension. In addition, there are a multitude of beneficial cardiovascular effects of regular physical exercise that result in physiologic, psychological, as well as biochemical improvements, all of which lead to a reduction in overall cardiovascular risk. These changes include reduction in the likelihood of obesity, improved blood pressure control in hypertensive individuals, reduction in serum cholesterol, decreased insulin resistance and other markers of inflammation, improved function and less stiffening of the large and small blood vessels, and reduction in the risk of pathologic blood clots. In contrast, physical inactivity and poor physical fitness are associated with a potentially harmful blood-clotting profile in middle-aged women with coronary heart disease.

Many women with multiple risk factors for heart disease are able to manage their risk factors through diet and exercise alone. For those women who require medical therapy to treat high cholesterol and high blood pressure, regular aerobic exercise provides an additional benefit.

Exercise in the Patient With Established CVD

CVD includes disease of the arteries of the heart, such as coronary artery disease (CAD), high blood pressure (hypertension; HTN), peripheral arterial disease (PAD), cerebrovascular disease, rhythm disturbances, diseases of the heart valves, and disorders of the small blood vessel not associated with actual blockages (small vessel disease). This entity of small vessel disease appears to be more common in women than men.

Exercise training is a significant component of rehabilitation of individuals who survive a heart attack (myocardial infarction; MI). Gradual, supervised regular physical exercise in survivors of MI not only introduces a healthy lifestyle habit to a potentially sedentary group but also enhances recovery from MI. Many of the benefits of exercise in this group include those described earlier but also include the psychological benefits afforded by regular physical activity. This is of particular value in this group due to the high prevalence of depression in survivors of MI and individuals who have undergone coronary artery bypass grafting. Female survivors of heart attack are much less likely than their male counterparts to participate in cardiac rehabilitation and currently miss out on the multiple beneficial aspects of this highly valuable but optional component of cardiovascular care.

The potential benefit of regular exercise in patients with PAD has also been demonstrated. A study examining the benefit of regular exercise in 118 patients with PAD demonstrated lower likelihood that the individuals who exercised would experience or die from a cardiovascular complication over the 5 years of follow-up.

Exercise can also lead to benefits among women with heart failure. Heart failure occurs when the heart can either not pump or not relax efficiently enough to deliver adequate blood supply to the body. Unfortunately, heart failure has reached epidemic proportions in the United States. Heart failure associated with abnormal heart relaxation (diastolic dysfunction) is common in women, particularly women over the age of 65. There is preliminary evidence available to suggest that regular physical activity not only treats the diastolic dysfunction but also treats the conditions that may be responsible for its presence in the first place, including obesity, high blood pressure, and diabetes. A recent large study examined regular aerobic exercise in men and women with reduced pumping function of the heart. This study found that regular aerobic physical activity leads to reductions in hospitalizations for heart failure and was not dangerous in this group of patients.

Exercise and Other Aspects of Women's Health

In addition to its beneficial effects on cardiovascular health, exercise has been shown to confer myriad other health benefits among women.

Exercise increases bone mineral density and, thus, prevents osteoporosis. Increased leisure-time activity, such as walking, has been shown to reduce the risk of hip fracture among postmenopausal women. It is worth noting that the beneficial effects of exercise may stem more from muscle strength, resistance, and balance training than from the intensity of the exercise itself. Furthermore, caution should be used in blanket recommendations to elderly women to exercise, as vigorous exercise among elderly patients may predispose them to the risk of falls and, thus, increase the risk of fracture.

In the realm of exercise and cancer, women who engage in regular physical activity have been shown to have a decreased risk of both colon and breast cancer. For women diagnosed with breast cancer, exercise has been shown to improve survival. As far as cancer risk is concerned, it is not entirely clear how much exercise confers risk reduction or at what stage of life. For breast cancer, it is postulated that exercise achieves this effect in women via reduction in adipose tissue and, thus, decreased overall estrogen production.

Finally, exercise has been shown to have numerous beneficial effects for women in terms of psychological well-being and cognitive function. Exercise has been shown to have utility in the treatment of major depressive disorder, with a dose-response effect, meaning that a certain level of exercise was necessary to achieve this response. Among women with premenstrual syndrome, exercise also seems to have a beneficial effect on both physiologic and psychological symptoms. Also for women with postpartum depression, a regular exercise program (three times per week) seems to mitigate depressive symptoms. Finally, among elderly women, a recent trial showed that a 6-month exercise intervention was associated with a modest improvement in cognitive function.

How Much and When?

Questions invariably arise when discussing the effects of exercise on women's health, namely, how much is exercise is enough and at what stage in life. These questions are difficult to assess because, as discussed earlier, exercise is associated with multiple different health benefits for women and each one may be associated with a different amount of exercise, at various stages of life. Thus, these questions continue to be investigated. For now, basic recommendations by the Centers for Disease Control and Prevention as well as the American College of Sports Medicine exist, suggesting at least 30 minutes of moderate-intensity physical activity on most days of the week. Indeed, a recent study following both men and women between the ages 50 and 71 years over time found that adherence to these guidelines, namely, engaging in moderately intense physical activity greater than 3 hours/week, led to a risk reduction of 27% in death from any cause among women in this age-group. This reduced risk was independent of other cardiovascular risk factors and body mass index.

Though these recommendations for a minimal amount of exercise exist, this does not mean that more exercise is not additionally beneficial. Again, the type of exercise, its intensity, and the age of greatest benefit depend on what outcome is being assessed. A recent prospective analysis among elderly women suggests that women who had previously had a sedentary lifestyle and began exercising after 65 years of age had reduced mortality.

Specifically, those women who increased their physical activity levels to a calorie expenditure equivalent to 1 mile (1.60 kilometers) per day of walking from their initial routine, to a follow-up 6 years later, had a reduction in cardiovascular mortality, cancer, and all-cause mortality. This benefit was not seen among women who began exercising after 75 years of age. Women who were consistently active, both before and after the 6-year intervention, had a similar risk reduction to those who only began exercising when the study began. Interestingly, recent physical activity levels were a better predictor of longevity than past. Another study, looking at 40,000 women, showed not only that there is a direct association between physical activity and decreased mortality but that the greatest benefit was seen among women who go from a sedentary lifestyle to one involving moderate physical activity.

Conclusions and Future Directions

In sum, exercise confers multiple health benefits for women. In the realm of cardiovascular health, exercise both prevents disease and improves outcomes among women with existing CVD. Exercise also has a role in mitigating cardiovascular risk factors, including hypertension, diabetes, and obesity.

Outside cardiovascular health, exercise has been shown to reduce the risk of osteoporosis, cancer, depression, and cognitive decline. Active investigation continues into optimal exercise regimens for women to achieve these health benefits, though research to date suggests that a clear health benefit occurs for most women who begin exercising, even if they have been inactive in the past.

Malissa J. Wood and Lisa Rosenbaum

See also Benefits of Exercise and Sports; Exercise During Pregnancy and Postpartum; Female Athlete; Female Athlete Triad; Strength Training for the Female Athlete

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World Anti-Doping Agency

The World Anti-Doping Agency (WADA) is a private Swiss law foundation, founded in 1999, responsible for ensuring fair competition in sports around the world. Its mission is to promote, coordinate, and monitor the fight against doping in all its forms. The WADA Code provides the basic framework for the agency's work, that is, "to protect the athlete's fundamental right to participate in doping-free sport and thus promote health, fairness, and equality for athletes worldwide." The objectives of the agency are to preserve the integrity and value of sports and youth, actively promote the "level playing field" philosophy, and act independently, professionally, and without bias or influence.

WADA is composed and funded equally by the Olympic movement and governments of the world. It is situated in Lausanne, Switzerland, and has its headquarters in Montreal, Canada. In 1999, the International Olympic Committee (IOC) held the first World Doping Conference in Sport in Switzerland. It was attended by the sports movement and representatives of several governments in an effort to establish an organized and cohesive plan to control a growing, complex problem in the world of competitive sports. There were several important results of this conference, including the establishment of the World Anti-Doping Code (the Code), the International Convention Against Doping in Sport (the Convention), and the Copenhagen Declaration on Anti-Doping in Sport (the Declaration).

Because many governments cannot be legally bound by a nongovernmental document such as the WADA Code, the International Convention was drafted under the auspices of UNESCO (United Nations Educational, Scientific and Cultural Organization), the body responsible for education, science, and culture. The Convention was unanimously adopted at the 33rd UNESCO General Conference in 2005. Separately, the Copenhagen Declaration was finalized at the World Conference on Doping in Sport in 2005. This declaration is the political document that signals a government's intention to formally recognize and implement the Code. As of 2007, 192 countries have signed the Declaration, and 80 UNESCO member states have become part of the Convention. In addition, more than 570 sports organizations have adopted the Code.

WADA is made up of a Foundation Board, an Executive Committee, and several other committees. The Foundation Board and Executive Committee comprise equally members of the Olympic Movement and governments. Government representation is allocated according to the five Olympic regions: Africa, Asia, the Americas, Europe, and Oceania (Australia and New Zealand). The Foundation Board has 38 members and is the agency's supreme decision-making body. The board delegates the management and running of the agency, including the performance of activities and the administration of assets, to the Executive Committee. Other committees such as the Athletic Committee or the Health, Medical and Research Committee act as advisors and provide guidance for WADA programs.

WADA received $18.3 million from the Olympic Movement to fund its first 2 years. Since 2002, funding was sourced equally from the Olympic Movement and the governments of the world. The governments agreed to a regional formula, and within each region, governments agree internally to each of their individual shares.

WADA prioritizes its work to focus on seven areas emanating from the Code.

1. *Code adoption, implementation, and compliance:* The agency ensures that sports and government agencies accept the principles of the Code. It assists in organizing a systematic testing process and ensures adjudication of results.
2. *Science and medicine:* WADA promotes global research to stay current on doping substances and methods. In addition, it maintains the annual List of Prohibited Substances and Methods, accredits antidoping labs worldwide, and monitors "therapeutic use exemptions."
3. *Antidoping coordination:* The Anti-Doping Development Management System (ADAMS) is the web-based database management system in place to assist stakeholders in coordination and compliance.
4. *Antidoping development:* The agency facilitates coordination of activities in regions where there are limited antidoping activities, so that resources can be pooled.
5. *Education:* WADA coordinates effective strategies and education to assist stakeholders in their education programs.
6. *Athlete outreach:* Antidoping experts take every opportunity, including one-on-one interaction at sporting events, to answer questions and educate athletes and stakeholders about the dangers and consequences of doping.
7. *Out-of-competition testing:* The agency contracts with stakeholders to help fulfill their responsibility for "no-notice out-of-competition" testing.

The Prohibited Substances and Methods list, as well as many other resources for athletes and stakeholders, is available on the WADA website and is updated annually (www.WADA-ama.org). The general categories of banned substances include androgenic anabolic steroids and other anabolic agents, hormones (e.g., growth hormone, erythropoietin, and insulin), hormone antagonists and modulators, beta-2 agonists, diuretics, and masking agents. Gene doping is specifically prohibited as well, although at this time, there is no reliable testing for this. Blood doping and other methods to enhance oxygen transfer are prohibited.

There is a process, of course, to ensure that an athlete who needs a substance that could be considered a doping agent for medical reasons, such as insulin or albuterol, can use it in a medically responsible way to treat an illness or condition. A Therapeutic Use Exemption (TUE) application is submitted to the athlete's local sports federation for review by a panel of independent physicians, called a Therapeutic Use Exemption Committee (TUEC). Preapproval, with possible monitoring of medication levels, is determined by the local federation. WADA does not accept TUE applications, but it has the power to overturn an exemption that has been granted or overturn a denial if it is determined that international standards were not followed.

There are three basic criteria to determine if an athlete will be granted a TUE: (1) the athlete would experience significant health problems without taking the prohibited substance or method; (2) the therapeutic use of the substance would not produce significant enhancement of performance; and (3) there is no reasonable therapeutic alternative to the use of the otherwise prohibited substance or method.

The problem of doping is an extremely complex one, often with enormous financial, political, and cultural implications. WADA has created an intricate system with checks and balances, as well as international representation to work for and protect athletes and sporting events, large and small, around the world.

Michael O'Brien

Websites

International Olympic Committee: http://www.olympic.org
National Collegiate Athletic Association: http://www.ncaa.org
World Anti-Doping Agency: http://www.wada-ama.org

Wrestling, Injuries in

Wrestling is a sport in which the clinician faces many unique challenges. A strong knowledge of infectious skin diseases and issues related to weight control is imperative for anyone concerned with this sport. Many common sports medicine injuries will be encountered in wrestling. One common injury definitively seen in wrestling is concussion.

Concussion

Concussion is defined as any impact to the head or to the trunk, chest, or neck that radiates force to the head. It is often believed that concussion needs to have loss of consciousness or amnesia associated with it, but this is not the case. Although common, these symptoms do not necessarily need to be present. Concussion is characterized by a spectrum of symptoms, including but not limited to headache, dizziness, nausea, vomiting, confusion, cognitive difficulties, and balance disturbances. These symptoms occur quickly after impact, are neurological in nature, and generally abate spontaneously over time. For an athlete experiencing symptoms, a complete physical examination, including a thorough neurological and mental status examination, should be performed. Diagnostically, a computed tomography (CT) scan or magnetic resonance imaging (MRI) scan is ordered by physicians to rule out further pathology, such as bleeding within the brain. Concussion is treated symptomatically. Only when an athlete is symptom-free, is not taking any medicines for symptom control, and has normal mentation can he or she be placed on a return-to-sport protocol. A symptomatic wrestler is never allowed to return to his sport.

Auricular Hematoma (Cauliflower Ear)

An auricular hematoma occurs from trauma to the cartilaginous portion of the ear. In this area, blood collects between the skin and cartilage. If not treated in a timely manner, the deformity to the ear can become permanent. Treatment is via aspiration of the blood before it clots and application of a pressure dressing or other device to avoid further bleeding and accumulation of blood.

Epistaxis (Nosebleed)

A nosebleed occurs most often when there is breaking of the small vessels at the front of the nose due to trauma. Quite often, wrestlers are prone to recurrent nosebleeds because of continued trauma to the nose. It is important to try to stop the bleeding as quickly as possible. This is done by tilting the head forward and pinching the nostrils until the blood stops. A cotton plug or dental gauze placed in the nose can continue to hold pressure so that a wrestler can finish the match. If the bleeding becomes recurrent, then cauterization of the nasal vessels can often lead to permanent relief of the symptoms.

Sprains and Strains

A sprain refers to an injury to a ligament where it is stretched or, in the worst case, completely torn. A strain refers to an injury to a tendon or muscle where it is "pulled" or partially torn. Sprains and strains can happen to any joint in the body and are common in wrestling due to the consistent contact between the wrestlers and the contact of the athletes with the mat surface. They are characterized by pain, swelling, redness, loss of motion, and loss of strength at a joint. During competition, sprains and strains can be treated by the PRICES protocol, which refers to *p*rotection of the joint, *r*est, *i*ce, *c*ompression, *e*levation, and *s*upport of the joint. Once a more severe injury is ruled out by either physical examination by a physician or further radiological studies, physical therapy, taping/bracing, and anti-inflammatory medications are used to try to treat these conditions. Unfortunately, many complete sprains, such as those of the anterior cruciate ligament, or tendon/muscle tears, such as that of the patella tendon, require surgical intervention to reestablish proper functioning of the affected joint.

Fractures

A fracture is a medical condition in which there is a break in the bone. It can happen to any bone in the body. In wrestlers, the bones that are frequently fractured are the nasal bones, the bones of the fingers or toes, and those of the wrist and ankle, though other bones may also undergo fracture. Fractures are identified by pain, swelling, bruising, and redness at a fracture site. Physicians are suspicious of a fracture if there is pain directly on a bone or if they can feel a break, or step-off, in the outer covering of the bone, or cortex, when they follow the smooth contour of a bone. There is also a loss of motion or strength if a joint is involved. In general, suspected fractures are splinted or braced at the site of competition, ice is applied, and the athlete is sent for confirmation of the fracture. X-rays, MRI, CT, or bone scan can confirm fracture in a wrestler. Fractures are treated by splinting or casting to allow bone alignment for healing. For those fractures whose alignment cannot be maintained by splinting or casting, surgery is necessary to insert hardware to keep the bone ends together in order to allow the fracture to heal.

Cervical Strain (Neck Strain) and Lumbar Strain (Back Strain)

This injury occurs when there is a strain or injury to the muscles of the neck/back, usually during a takedown or bridging. It is characterized by pain and sometimes spasm of the muscles that line the spinal column. As long as there is no injury to the spinal cord or column, this injury usually heals without much difficulty. Treatment is icing and anti-inflammatory medications to the neck/back as well as physical therapy to the neck/back muscles to stretch and strengthen them.

Dislocated Shoulder

This injury occurs when the humeral head, or top of the arm bone, becomes separated from the glenoid, or shoulder bone. There is often pain deep within the shoulder and possibly numbness down the arm on the same side. One can often see the top of the humerus, either in front or behind the glenoid. When this occurs, it is important to be sure that the athlete has normal neurovascular status and absence of obvious fracture before even considering reducing or putting the shoulder back in place. If there is no qualified person available, the arm should be splinted and the athlete sent to the hospital for reduction. An X-ray at the hospital can then aid in determining the position of the humerus, rule out fracture, and assist in the reduction. Once reduced, the shoulder is checked for further pathology with an MR arthrogram. If there is no further pathology, physical therapy should bring the shoulder back to normal function. If there is further pathology, often surgery is performed to repair the damaged soft tissue structures and prevent another episode of dislocation.

Acromioclavicular (AC) Separation (Separated Shoulder)

This occurs when a wrestler lands directly on his or her shoulder, usually during a takedown. This results in a sprain of the ligament between the acromium, or shoulder bone, and the clavicle, or collarbone. This is often demonstrated by the clavicle being elevated above the acromium. An X-ray can confirm this. This injury often responds well to physical therapy and usually does not require surgical intervention.

Brachial Plexopathy (Burner or Stinger)

This injury occurs when the neck is forcibly side bent as the shoulder on the same side of the body is depressed, causing a stretch of the brachial plexus, the site where the nerves that innervate the upper extremity on the affected side exit out the neck and through the shoulder area. This can happen when a wrestler is forcibly taken to the mat. The wrestler usually complains of burning pain from the base of the neck through the entirety of the affected extremity. The condition usually lasts seconds with an initial episode but takes longer to resolve after each successive episode. The pain usually resolves on its own in several seconds to several minutes depending on the number of past episodes a wrestler has endured. There is generally no work-up done by the physician unless the condition becomes chronic. In this case, X-rays are ordered to look for bony structural issues that may be causing the injury. These may be followed by MRI or CT scan to further evaluate both bony and soft tissue structures to determine if there is an anatomical reason for the injury and to determine whether the wrestler should be removed from the sport because of the danger of neurological damage from repetitive injury due to his or her anatomy. Initial stingers are usually returned to play once the symptoms have resolved. Those who have repetitive episodes will need further examination to make sure that anatomy is not contributing to the injury and usually undergo a cervical stretching and strengthening program to prevent further injury.

Ulnar Collateral Ligament Sprain of the Elbow

The elbow is essentially a hinge joint made from the coming together of the radius and ulna (the two smaller forearm bones and the larger humerus, or upper arm bone). Wrestlers typically suffer injury to the ulnar collateral ligament of the elbow, which is the ligament connecting the ulna and humerus, when posting after a takedown or during an arm chop when the wrestler is beginning on the bottom position. Both these maneuvers can lead to stress on this ligament and a possible stretch, sprain, or tearing of the ligament. The physician can check the integrity of the ligament by putting force on it. If moves and "gaps" are more than on the opposite side, there is concern for a sprain or tear. An X-ray can determine if this is due to fracture. MRI can show the extent of damage to the ligament. A complete tear would require surgical repair in a wrestler. A sprain would require possibly bracing to let the ligament begin to heal, followed by physical therapy to regain normal elbow function.

Ulnar Collateral Ligament Tear of the Thumb (Gamekeeper's Thumb)

This injury occurs when the thumb is abducted or forced away from the rest of the hand. This movement may sprain or tear the ulnar collateral ligament that connects the proximal phalanx of the thumb to the first metacarpal. Wrestlers with this injury cannot oppose the thumb. An X-ray can rule out fracture at the joint. MRI can show damage to this ligament. Treatment involves casting or splinting of the thumb for sprains and surgery for complete tears.

Back Pain

Back pain in wrestling is usually due to a muscle strain or "pulled muscle" during competition. Some forms of back pain in wrestling are not due to muscle strain. One such cause is herniation of a vertebral disk. Disk herniation occurs when the soft jelly-like part of the disk escapes through a tear in the annulus fibrosis, which is the tougher covering of the disk. When radicular symptoms, pain or numbness occurring in either lower extremity or both, are present, the pain may be due to a herniated disk causing stenosis or pressure on the nerve that innervates that particular lower extremity. A less common cause of back pain sometimes found in wrestling is a spondylolysis, or stress fracture of the pars portion of the vertebra. This can occur due to the consistent flexion and extension of the back while wrestling. Physical examination, X-rays, MRI/CT scans, and bone scans can often elucidate which of these conditions is causing the back pain. Muscle strains, herniated disks (with and without stenosis), and annular tears are usually treated conservatively with rest, icing, physical therapy, and anti-inflammatory medications. Epidural injections, injection of cortisone at the area of disk herniation, or surgery, may be needed if pain cannot be treated conservatively. Return to sports is usually guided by pain tolerance in the wrestler unless neurological symptoms occur. Spondylolysis treatment is more controversial. Many physicians recommend physical therapy and return to sports when painfree. Others recommend bracing followed by physical therapy and then return to sports. There is no consensus on treatment for this condition.

Trunk Pain

Pain in the area of the trunk is common in wrestling. This is often caused by movements in which one wrestler grasps the other wrestler, trying to expose his or her back. Pain in the rib area can be due to rib fracture or due to a strain of the small muscles between the ribs, the intercostals. It can also be due to strain of any of the abdominal muscles. Symptoms of rib fracture or muscle strains in the trunk can include pain at the site of injury, pain with movement, or difficulty breathing. With pain, an immediate physical examination should be performed, including listening to the lungs, to be sure that a fractured rib has not pierced a lung, creating a pneumothorax. X-rays are diagnostic of rib fractures. Treatment for rib fractures as well as strains includes rest, icing, medications for relief and pain, and physical therapy. Return to wrestling after a rib fracture is allowed when the fracture has healed, to avoid pneumothorax. Pain is the guide for wrestlers with simple strains.

Groin Strain (Groin Pull)

A strain of the muscles of the groin can occur in an area where the external rotators or flexors of the hip are located. This injury is characterized by movement in these planes. These injuries are usually self-limiting but can take several weeks to heal. Treatment is usually with rest, icing, anti-inflammatory medicines, and rehabilitation.

Knee Meniscal Tear

The meniscus is the shock absorber found between the femur, or upper leg bone, and tibia, or lower leg bone. There is one on the inside of the knee, or medial, and one on the outside, or lateral. Meniscal tearing occurs during a plant-and-twist injury, such as getting a foot caught in the mat when the wrestler is attempting to escape his or her opponent. Wrestlers often report feeling or hearing a “pop” or “tear.” This is often accompanied by swelling within the knee and pain at the knee joint line. Often, it is difficult to walk on the affected leg. Physicians can test the affected meniscus for tearing by performing the McMurray test. In this test, the physician attempts to catch a piece of the damaged meniscus between the femur and tibia by manipulating the knee. X-rays cannot reveal a meniscal tear. An MRI test usually can detect meniscal tears. Meniscal tears are treated usually by surgery to either repair the damaged meniscus, if good blood supply is present, or remove the damaged part of the meniscus in a procedure called a partial meniscectomy. Surgery is usually followed by physical therapy. Meniscal tearing that does not produce symptoms can also be treated by physical therapy with or without cortisone injection.

Patella Dislocation/Subluxation

The patella is also called the kneecap. It sits in the groove of the femur, or top leg bone, and aids in extension of the knee. It is stabilized at the top of the bone by the quadriceps tendon and on the bottom by the patellar tendon. With certain moves, the patella can reach the edge of the groove and almost slide over it, referred to as a subluxation. If the kneecap does in fact pass over the groove, it is referred to as a dislocation. The kneecap often moves laterally, or to the outside of the leg, with this movement. Patients often complain of hearing a “pop,” have immediate pain and swelling at the knee, and may visualize the kneecap on the outside of the femoral groove. Often, the kneecap will go back into place as the wrestler moves secondary to the pain he or she has from the displacement of the kneecap. If it does not go back into place on its own, the kneecap is often stabilized with an immobilizer or a brace. The physician usually performs an Apprehension Test, where he or she places outside stress on the kneecap to see if the symptoms of kneecap subluxation/dislocation can be mimicked. X-rays are often taken to ensure that there is no fracture, and the physician will manipulate the kneecap back into place. This may be followed by an MRI test to be sure that there is no subtle fracture that was missed by the X-ray or that there is no tearing of important soft tissue structures holding the kneecap in place. Surgery may be necessary to repair these tissues. Physical therapy is then done to maximize function and strength, either after surgery or in the absence of soft tissue damage after a patella dislocation.

Prepatellar Bursitis

The patella has a fluid-filled sac, called a bursa, between it and the underlying soft tissue. This bursa is necessary to allow the soft tissue structures above the patella to pass over the bone without causing injury. In competition, wrestlers often land directly on their knees, causing a compressing force on the bursa as it is trapped between the bone and the mat surface. This can lead to an inflammation of the bursa or bursitis. The hallmark of a prepatellar bursitis is swelling just above the patella. The swelling feels like a fluid-filled sack and renders the knee painful when one tries to kneel on the affected knee. There are usually no tests used to diagnose this problem as its appearance itself is diagnostic. Often, the bursal fluid will recede on its own. If the fluid does not recede on its own, it can be aspirated by a physician. Once recovered, the wrestler can return to competition. If the bursa becomes infected, the condition is called a septic bursitis. Antibiotics are usually given to the athlete to treat the infection, and aspiration is delayed until the infection has cleared.

Ankle Sprain

An ankle sprain is caused when the foot either turns out (or everts) or turns in (or inverts) during activity as the body weight passes over it. The athlete at the time of the sprain sometimes hears a "pop" followed by immediate pain and swelling in the affected area of the ankle. Walking, or ambulation, is often difficult, and crutches must sometimes be used. Once an ankle sprain occurs, the ankle is usually immobilized and iced immediately. The physician usually checks range of motion and strength to assess damage to the joint. Certain tests, such as the Anterior Drawer Test or Tilt Test, check the integrity of the ligaments after a sprain. X-rays are often ordered to rule out associated fractures. Weight-bearing X-rays may be performed to be sure that the bones of the ankle have retained their alignment or have held together the functioning unit of the ankle, called the *mortise*. MRI may be necessary to look at the soft tissue damage more intently or determine if there has been damage to the ligaments or soft tissue between the tibia and fibula that may necessitate early surgical intervention. Simple ankle sprains are generally treated with protection, rest, ice, compression, elevation, and support. Physical therapy is usually necessary to restore movement and function.

First Metatarsal Sprain (Turf Toe)

This condition refers to a sprain of the collateral ligaments—or ligaments that connect the two sides of a joint—that connect the first metatarsal, or last foot bone, to the proximal phalanx, or first toe bone. The condition gets its name commonly from football, where the first toe can be sprained when it gets caught in the artificial turf during play. The principle is the same in this case, as the toe gets caught in the mat and sprains the joint. The athlete commonly complains of loss of motion and/or strength, pain, swelling, and possibly redness at the site. After the physician checks motion and strength, X-rays may be obtained to be sure that there is no underlying fracture at the joint. If there is no fracture, treatment consists of applying ice to the joint, therapeutic taping, physical therapy, and sometimes shoe modification to make the sole of the wrestling shoe stiffer in order to keep the toe straight. Pain is usually the limiting factor for the athlete's return to play.

R. Robert Franks

See also Acromioclavicular (AC) Joint, Separation of; Ankle Sprain; Bursitis; Cervical Nerve Stretch Syndrome; Concussion; Ear Injuries; Fungal Skin Infections and Parasitic Infestations; Lower Back Injuries and Low Back Pain; Meniscus Injuries; Nose Injuries; Patellar Dislocation; Skin Infections, Bacterial; Skin Infections, Viral; Thumb Sprain; Wrestling, Injuries in

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Wrist Dislocation

The wrist joint serves as a link between the hands and the upper body, and a great deal of force is transmitted through this joint. The specific arrangement of bones and the presence of ligaments provide flexibility to the joint. Although this flexibility helps in the movement of our hands and fingers, it also allows for dislocation.

Wrist dislocation means that the wrist bones have been knocked out of position or a bone has come out of place in the wrist joint. It is sometimes also referred to as carpal dislocation. Such an injury is common among athletes. It is usually experienced in sports with increased force vectors (height and speed), for example, adult inline skaters and football players. Other cases include falls from a height, as seen, for example, in gymnasts.

The most common cause of injury is high energy, but low-energy trauma has also been described as the cause of carpal dislocation in some reports.

Wrist dislocation is a serious injury and requires immediate emergency care. In a study by Larsen and Lauritsen, as many as 2.5% of all cases presented in various emergency departments of the United States are wrist injuries. Ten percent of all carpal injuries are subluxations and dislocations, perilunate dislocation being the most common type.

The initial evaluation and treatment of wrist injuries can be performed by emergency physicians and/or family practitioners. Early recognition of a dislocation and determination of proper treatment can prevent complications, including prolonged pain, discomfort, and surgery, and time lost from sports participation.

Anatomy

The wrist comprises 10 bones: 8 of these are the carpal bones, and the remaining 2 are (lower ends of) the forearm bones (see Figure 1).

The carpal bones are arranged in two rows and include the scaphoid, lunate, triquetrum, and pisiform in one row and the trapezium, trapezoid, capitate, and hamate in the other. The forearm bones are the radius and the ulna.

A complex set of ligaments holds the carpal bones together and assists in movement. These ligaments are named according to the bones they hold together. Dorsal ligaments are weaker than other ligaments; making this side of the joint more vulnerable to dislocations.

Types of Wrist Dislocation

Wrist dislocations can be divided into two types:

Perilunate dislocations: The lunate remains aligned with the radius, but the capitate dislocates. It is more common than lunate dislocation as the radial-lunate ligaments are stronger than the lunate-capitate ligaments. Seventy-five percent of the cases are associated with scaphoid fractures (known as trans-scaphoid perilunate dislocation).

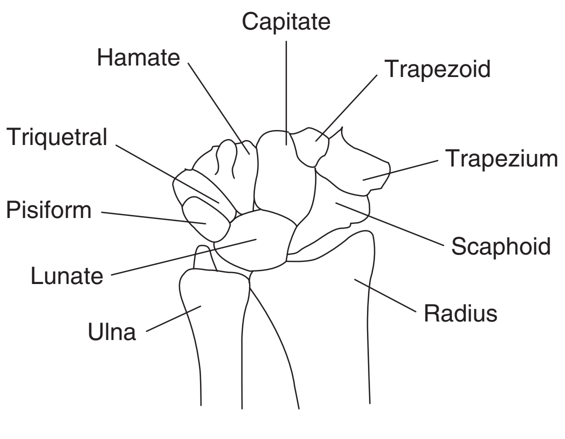

Figure 1 Bones of the Wrist Joint

Lunate dislocations: In these, the lunate bone dislocates, and the other carpal bones remain in alignment. This type of dislocation is less common than perilunate dislocation.

Causes

Wrist dislocation can occur as a result of either of two causes:

1. *Repetitive activity:* Repeated stress on the carpal ligaments renders them more prone to injury, especially in athletes. In some cases, the overuse may be so great that the wrist bones slip.
2. *Trauma:* Sudden extreme pulling or stretching of the ligaments or a severe blow to the bones, commonly due to falling on an outstretched arm, can result in dislocation. This type of dislocation most commonly involves displacement of the lunate bone, but other bones of the wrist can also be involved.

Stages of Dislocation

Mayfield and coworkers have classified wrist dislocation into four stages:

Stage I: Scapho-lunate dislocation due to a tear in the ligaments holding these bones together

Stage II: Lunate-capitate subluxation that results from injury to the capito-lunate joint

Stage III: Lunate-triquetral dislocation resulting from injury to the ligament

Stage IV: Lunate dislocation resulting from injury to the dorsal radio-lunate ligament (the ligament that holds the lunate against the radius)

Clinical Evaluation

The evaluation of a wrist dislocation begins with a history and physical exam.

History

The typical history is one of a person who attempts to brace for a fall. The force of the body landing on the palm results in a dislocation. Sometimes athletes can dislocate their wrist on falling on an outstretched hand when they have mistimed a landing, as in gymnastics. Wrist dislocation is also seen in football, where defenders try to stop oncoming forces with resistance. Often the resistance is great enough to lead to a wrist dislocation.

Physical Examination

On physical examination, the following signs and symptoms are observed in a case of wrist dislocation:

- Extreme pain at the time of the injury that worsens with movement
- Loss of wrist and hand mobility or decrease in the range of motion
- Deformity or contortion of the wrist
- Tenderness around the wrist and hand area
- Swelling of the wrist
- Hand weakness (unilateral)
- Decrease in grip strength
- Numbness and paralysis of the hand in case of severe injury (due to pressure, pinching, or cutting of blood vessels or nerves)

Sometimes neither the patient nor the physician is able to appreciate the severity of the trauma, and the dislocation may present itself after a delay. Therefore, during the evaluation of a patient with wrist injury, dislocation should always be suspected.

Diagnostic Tests

Sometimes tests are required to make the diagnosis of a wrist dislocation. Tests that can be done include the following:

X-rays of the wrist: Radiographs of both hands are taken for comparison, and bone alignment is checked along various planes/axes.

Bone scan: A radioactive tracer is injected into the blood and gets attached to all the bones of the body. A computer scan generates a picture of the skeleton by reading the radiation levels. Any abnormalities are easily observed.

Magnetic resonance image (MRI) of wrist: An MRI scan provides good resolution of soft tissue as well as bone.

Wrist arthroscopy: This is a surgical procedure used to diagnose and treat problems inside a joint. Small incisions are made around a joint, and a pencil-sized instrument called an arthroscope is inserted. The arthroscope contains a miniature lens and camera, which project the three-dimensional images of the joint onto a screen.

Arthrography: It is useful in detecting tears of the ligaments.

Treatment

Nonsurgical Approach

All types of injuries need to be assessed by a physician. If there is no evidence of fracture and the injury is not very severe, the wrist bones may align themselves properly and heal with time. There may be a need for repositioning the bones to reduce the dislocation. If there is an associated wrist fracture, surgery is performed to restore the joint to its normal position.

Surgical Approach

Surgical reconstruction or replacement of the joint is required in acute or recurring dislocations. It is performed under anesthesia. The surgeon opens the hand and wrist area and aligns the bones properly. In case of major damage, other devices such as surgical screws may also be used.

Associated Measures

Along with treatment, the following measures should be incorporated to enhance successful healing:

- Elevation of the wrist
- Rest and immobilization, perhaps with a sling for 2 to 8 weeks
- Ice, which helps in reducing acute pain and swelling
- Compression of the wrist (cold compresses may be used)
- Elastic (ACE) wrap
- Cast or splint for a wrist dislocation
- Physical therapy for a wrist dislocation, including exercises designed to build up the muscles of the hand and wrist, helpful in restoring full functional strength and motion in the hand and wrist
- Occcupational therapy for a wrist fracture

Symptomatic Treatment

The following medications may be included in this treatment:

Nonsteroidal anti-inflammatory drugs (NSAIDs): These lower the elevated body temperature and relieve pain without impairing consciousness and have anti-inflammatory effects.

Narcotic pain medication: These are strong pain relievers and cause loss of feeling.

Prevention

Use of gloves, wrist guards, or tapes, if the sport permits, can provide some protection to the wrist. Implementation of proper technique and maintenance of good strength and good flexibility can prevent wrist injuries. In case of an injured wrist, the patient should return to play only after achieving full recovery.

Return to Sports

The dislocated joint and the injured ligaments require a minimum of 6 weeks for complete healing. On returning to work, the patient may support the wrist with a tape or a brace initially if he or she is required to perform lifts or bear weight on the involved wrist.

Sometimes, undergoing special exercise programs, physical therapy, or occupational therapy to restore full strength may be necessary. A physician should be consulted in all cases before resuming routine physical activities.

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See also Wrist Fractures; Wrist Injuries; Wrist Sprain; Wrist Tendinopathy

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Wrist Fracture

In sports, the wrist is one of the most vulnerable parts of the body. Wrist fractures are among the most common sports-related injuries. Surveys have shown that women, beginners, and younger athletes are more prone to wrist injuries, and it is recommended that they wear wrist guards that help protect the wrist from injury.

Wrist fracture is the most common fracture in patients under 65 years of age and accounts for about one sixth of all factures seen in hospital emergency departments. It is defined as a break in one or more of the bones in the wrist, but when clinicians are describing wrist fracture, they are usually referring to a fracture of the distal end of the radius (one of the two bones in the forearm, the other being the ulna). The other bones of the wrist joint may also be broken, but the term *wrist fracture* usually implies a fracture of the end of the long bone of the forearm.

Fractures of the wrist most commonly occur as the result of a person extending his or her hand to break a fall, due to which a large amount of force is applied to the wrist, causing the fracture (usually seen in sports where a fall on a hard surface is likely, such as skating, basketball, and hockey); or they may be due to a large force being directly applied to the wrist (e.g., a direct blow during contact sports or a blow from a stick, as in hockey or lacrosse). Injuries related to sports, car accidents, and falls from a height are important contributing causes of wrist fracture. In older individuals, osteoporosis may play a significant role by making the bones brittle and more susceptible to fractures, even with minor trauma.

Anatomy

The wrist is made up of two long bones in the forearm (ulna and radius) and eight short bones (carpal bones). The radius is located on the thumb side of the forearm, while the ulna is located on the side of the little finger. The carpal bones are situated in two rows (four in each) at the wrist joint and have synovial joints between them, but movement at these joints is restricted. The ulna and radius are joined at the proximal radio-ulnar joint near the elbow and the distal radio-ulnar joint at the wrist.

The wrist joint is a complex synovial joint between the distal end of the radius and the end of the ulna with the proximal row of carpal bones (the distal row of carpal bones make the carpo-metacarpal joints with the metacarpal bones of the hand). The joint between the radius and ulna is fixed due to the articular disk covering the end of the ulna. The surfaces of carpal bones form a convex contour that articulates with the concave surface of this articular disk and radius. At each joint, the end of the bones is covered by a cartilage, which allows for smooth movements. The bones are held together by ligaments. The joint cavities are filled with synovial fluid, which reduces friction. This arrangement allows for movement at the wrist around two axes, side to side, and the bending and straightening of the wrist. Rotation of the wrist is brought about by combinations of these movements.

In addition, there are a number of nerves and blood vessels traversing this region that may be damaged due to injury to the wrist.

Classification of Wrist Fractures

Generally, the different patterns of fracture of the wrist are the Colles fracture, the Smith fracture, the Barton fracture, and the Chauffer fractures. The classification of fractures is based on the pattern of injury involved, the behavior and outcome of that pattern, and the need to distinguish between conditions requiring different treatment strategies. Furthermore, the fracture may be extraarticular or intraarticular (extending into the joint cavity or not), it may be a closed injury or a compound fracture, and comminution (the amount of crumbling at the fracture site) may be extensive or minimal.

In assessing the stability and determining treatment, many features of the fracture must be considered, such as radial shortening, radial angulation, comminution, articular incongruity, accompanying soft tissue injuries, and associated ulnar fractures.

In addition, other bones of the wrist may also be broken in wrist fractures, the most common being the scaphoid (carpal bone articulating with the radius) (Figure 1a) and the "hook" of the hamate (Figure 1b).

Symptoms and Evaluation

Wrist injuries inflicted in vehicle accidents or sports or in any other way can result in wrist fractures. The first symptom experienced by the person is pain that occurs immediately after the injury and does not subside. The intensity of pain varies with different kinds of fractures and from person to person. Other symptoms may be swelling and tenderness around the wrist, bruising around the wrist, limited range of motion of the thumb and wrist, and visible deformity of the wrist. These symptoms can also be due to other conditions, so it should not be assumed that there is a fracture. A doctor should be consulted.

Diagnosis can be made by observing the deformity of the distal radius, but it should be confirmed by an X-ray. Computed tomography (CT) scans and magnetic resonance imaging (MRI) can also be helpful in confirming the diagnosis if fractures are not seen on X-ray immediately after the injury.

Treatment

The treatment differs widely depending on the nature and severity of the injury. The treatment plan consists of the following:

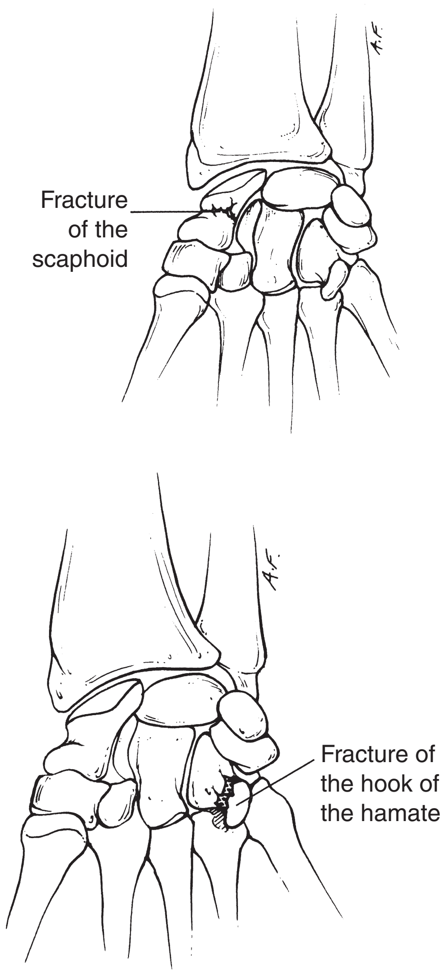

Figure 1 Wrist Fractures

Note: (a) Fracture of the scaphoid and (b) fracture of the hook of the hamate.

- It involves approximating the pieces of the fractured bone together, which may require anesthesia and also may require surgery.
- The pieces of bone should be kept in position while the bone heals and the ends join.

After the reduction of the fracture, different modalities may be employed to hold the bone in place (stabilization):

- A cast may be used with or without surgery.
- Internal fixation may be done with a metal plate and screws.

- Percutaneous pin fixation may be done.
- External fixation may be done.
- A combination of these modalities may also be used.

The typical treatment is immobilization with a plaster of paris cast for 5 to 6 weeks to allow union of the bones. The use of other modalities depends on the nature and extent of the injury, and appropriate treatment for each case is determined by the surgeon. For athletes requiring the use of their wrist, such as in tennis, motocross, or cycling, recovering from a fracture without stiffness is important. This is done by performing surgery only when necessary to realign the bones and treating postsurgery without a cast to allow early motion of the wrist and fingers. Due to the functional importance of the hand, the period of immobilization is kept to a minimum to avoid dysfunction of the hand and wrist. The more motion these patients have, the easier it is to resume their sport.

Follow-Up and Recovery

It is common practice to repeat X-rays at about 1 week during the follow-up period. Follow-up is also needed to determine when the cast may be removed, when the fracture has healed and the rehabilitation is complete. Removal of the cast is followed by rehabilitation for 1 month or more, a short period of which may involve the use of a wrist brace for comfort.

Return to sports should be decided by the patient's physician. Braces should be used to stabilize the wrist during sports or even normal activities. In most cases, athletes can return soon after the immobilization with some protection for the wrist or after adequate postoperative healing, as recommended by the doctor. When the pain subsides, the athlete should work on strengthening the wrist and improving its function, as directed by the doctor. This is usually achieved by performing stretching exercises such as

- wrist range of motion,
- wrist stretch,
- wrist extension stretch,
- wrist flexion stretch, and
- forearm pronation and supination.

These are followed by strengthening exercises such as

- wrist flexion,
- wrist extension, and
- grip strengthening.

It is important during fracture healing that the flexibility of the fingers and hand be maintained. The patient may start hand and wrist exercises as soon as the wrist is stable, to recover the flexibility, strength, and function of the wrist. It is recommended to stay off sports for 6 weeks at least, but the time for recovery varies according to the severity of injury, on any associated injury, and on factors related to the individual. Full recovery may take 6 to 12 weeks, when the patient may resume normal activities, but it is not unusual for maximal recovery from a wrist fracture to take several months. Some patients may, however, have residual stiffness or pain, and even arthritis may develop. On occasion, reconstructive surgery or additional treatment may be required.

Prevention

Certain risk factors increase the chance of developing wrist fractures:

- Advancing age
- Postmenopause
- Poor nutrition
- Osteoporosis
- Decreased muscle mass
- Contact sports such as soccer or rugby
- Skating, bike sports, skateboarding
- Vehicle accidents

Risk of injury may be avoided by following these simple guidelines:

- Putting oneself at risk for trauma should be avoided.
- The diet should include adequate calcium and vitamin D.
- Proper safety equipment should be used in sports training and contests.
- Fair play and a healthy competitive spirit should be practiced.

- Rules must be enforced to minimize risk of injury to players.
- The athletes should be provided proper coaching and training by qualified specialists.

Prompt medical attention should be easily available to the athlete at all times, especially in cases of emergency.

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See also Musculoskeletal Tests, Hand and Wrist; Taping; Wrist Injuries; Wrist Sprain

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Wrist Injuries

The wrist is frequently injured in sports. Sprains are the most common wrist injury, accounting for 20% to 50% of injuries, followed by contusions (15%–30%) and fractures (5%–35%). Distal radius fractures are the most common fracture seen in emergency departments; scaphoid fractures are the most common carpal fracture. Acute injuries of the wrist occur in sports such as football, hockey, and snowboarding, most often from falls. Falls resulting in wrist injuries can also be seen in recreational activities such as rollerblading and biking. Overuse wrist injuries occur in sports such as golf, gymnastics, and racquet sports. It is important to recognize wrist injuries and ensure appropriate treatment to avoid impairments that may affect not only sports participation but also activities of daily living.

Wrist injuries are more common in children and adolescents than in adults participating in sports. Wrist and hand injuries account for between 3% and 20% of all athletic injuries in the younger population. Possible reasons to explain this increased frequency of wrist injuries in young athletes include increased sports participation by younger athletes; the increased popularity of "extreme" sports; the use of age- or size-inappropriate equipment; increased risk of injury of the immature musculoskeletal system in children, particularly with excessive frequency or intensity of certain sport-specific activities; and poor sport-specific techniques, poor supervision, and inadequate coaching.

Anatomy

The joints of the wrist include the radiocarpal joints and the distal radioulnar joint. The radius articulates mainly with the scaphoid. The ulna articulates primarily with the lunate. Movement at the radiocarpal joints includes flexion-extension and radioulnar deviation. Movement at the distal radioulnar joint includes pronation-supination.

The carpal bones in the wrist consist of a proximal row, including the lunate, triquetrum, and pisiform, and a distal row, including the trapezium, trapezoid, capitate, and hamate. The proximal and distal rows of carpals are bridged by the scaphoid bone. The ossification centers of the carpal bones appear on X-rays in a predictable pattern. The capitate appears first at less than 1 year of age, followed by the hamate, triquetrum, lunate, scaphoid, trapezius, trapezoid, and pisiform. All ossification centers are apparent on X-rays by 10 years of age. The distal radial epiphysis appears by 1 year of age, whereas the distal ulnar epiphysis becomes visible by 6 to 7 years of age. These physes close by 16 to 18 years of age, when skeletal growth has been completed. Knowledge of the appearance of these ossification centers and epiphyses can help avoid confusion between normal structures and possible fractures and bony injuries in children and adolescents.

Wrist stability is imparted by several extrinsic and intrinsic ligaments. The carpal bones are stabilized by the intercarpal ligaments and allow for transmission of forces across the wrist. There are many extrinsic tendons that traverse the wrist, including the wrist flexors (flexor carpi radialis, palmaris longus, flexor carpi ulnaris) and wrist extensors (brachioradialis, extensor carpi radialis longus, extensor carpi radialis brevis, extensor carpi ulnaris).

Evaluation of Injuries

Details of Injury

The mechanism of injury, including the position of the wrist, the direction and magnitude of the involved force, and subsequent symptoms of weakness, pain, or instability, can help determine the cause of wrist pain. Acute injuries are usually the result of a *f*all *o*n an *o*ut*s*tretched *h*and (FOOSH). Striking a solid object with a piece of equipment, such as a bat, golf club, or tennis racquet striking the ground, can result in a fracture of the hook of the hamate. Rotational stress to the distal radioulnar joint, as well as forced ulnar deviation and rotation, may result in a tear to the triangular fibrocartilage complex (TFCC). More severe wrist injuries may prevent an athlete from returning to activity immediately following injury.

The exact location of pain helps narrow the differential diagnosis. Wrist injuries may result in mechanical symptoms such as clicking, snapping, or swelling. Previous injuries to the upper extremities may predispose an athlete to wrist injuries. Other important details such as hand dominance, type of sport, position played, level of performance, and occupation may affect management of the injury.

Physical Findings

Wrist injuries may cause obvious deformity, swelling, or bruising of the wrist. The athlete may hold the wrist in various positions to avoid pain. The range of motion of the injured wrist may be decreased flexion-extension, supination-pronation (hand down/hand up), and radial-ulnar deviation. Normal range is 20° of radial deviation and 60° of ulnar deviation. Comparing the range of motion of the injured wrist with that of the uninjured side can emphasize any decreased movement of the injured wrist. Decreases in wrist movement can also be seen when the hands are placed in the "prayer position" and "reverse prayer position." The prayer position evaluates wrist extension. The patient apposes the palms with the elbows flexed and the wrists extended. Normal range of motion is 70° of wrist extension. The reverse prayer position evaluates wrist flexion. The patient apposes the dorsal aspects of the hands with the elbows and wrists flexed. Normal range of motion is 80° of wrist flexion.

Bony injuries of the wrist may result in tenderness to palpation or deformity. Bony prominences that may be tender to palpation include the distal forearm, the radial snuffbox, the base of the metacarpals, the lunate, the head of the ulna, the radioulnar joint, the pisiform, and the hook of the hamate.

Special tests of the wrist that may point to a specific injury include the Watson test and TFCC integrity. The Watson test evaluates scapholunate stability. The examiner places a thumb on the scaphoid tuberosity with the patient's wrist in ulnar deviation. The wrist is then deviated radially while the examiner applies pressure on the scaphoid. A positive test for scapholunate dissociation occurs if the patient feels pain dorsally over the scapholunate ligament or the examiner feels the scaphoid move dorsally. Assessment of TFCC integrity involves placing the athlete's wrist in dorsiflexion and ulnar deviation and then rotating the wrist. A positive test for a tear of the TFCC occurs when overpressure causes pain and occasional clicking at the ulnar aspect of the wrist.

Wrist injuries may result in nerve damage or injury to the blood vessels in the wrist as well.

Investigations

In the setting of a traumatic wrist injury, routine X-rays can show possible fractures. X-rays should include posterior-anterior (PA), lateral, and PA with radial and ulnar deviation views. If a ligament injury is suspected, a PA view with a clenched fist can indicate possible injury. The normal PA view should demonstrate a smooth line joining the proximal ends of the proximal row of carpal bones and the "C" shape of the midcarpal joint (the Gilula arcs). On the normal lateral view of the wrist, the proximal pole of the lunate fits into the concavity of the distal radius, and the convex head of the capitate fits into the distal concavity of the lunate. These bones should be aligned with each other and the base of the third metacarpal.

Specialized X-ray views can be ordered for specific suspected injuries. If a scaphoid fracture is of concern, scaphoid views should be obtained. A carpal tunnel view with the wrist dorsiflexed allows the hook of the hamate and ridge of the trapezium to be inspected.

Other modalities that are helpful to diagnose wrist pain, such as ganglions or occult fractures, include ultrasound, radionuclide bone scan, computed tomography (CT) scan, and magnetic resonance imaging (MRI). Ultrasonography is helpful to assess soft tissue abnormalities such as tendon injury, ganglions, synovial cysts, or thickening. Bone scans are helpful to rule out subtle fractures. CT scans can also evaluate fractures that may not be apparent on plain films. MRI can evaluate soft tissue injuries, such as a tear of the scapholunate ligament, more effectively than CT. Arthroscopy is an increasingly used procedure for diagnosis and therapy. It is an excellent tool for detecting scapholunate tears and is the investigation of choice for patients with ulnar-sided wrist pain that persists following an acute injury (see Table 1).

Prevention of Injury

Many wrist injuries in sport can be prevented. The use of protective wrist guards has been shown to reduce wrist fractures in sports such as snowboarding and inline skating. Studies have shown that the incidence of wrist fractures was reduced by half in participants who wore wrist guards while snowboarding. Similar studies on inline skating found that athletes who did not wear wrist guards were more than 10 times more likely to injure their wrist than those who did wear wrist guards.

In younger athletes, it is important to use age- and size-appropriate equipment to reduce injury. For instance, studies on youth soccer have shown that distal radius fractures are more common in younger children using an adult-sized ball than in those who use a junior-size ball.

Return to Sports

Return-to-play recommendations vary somewhat according to the specific injury, the treatment modality, and the sport-specific demands of the individual athlete. In general, full unprotected return to play is not allowed until the athlete has regained full active and passive range of motion and almost full strength of the affected wrist. Bony or ligamentous injuries usually require 3 to 6 weeks to heal. Athletes should not participate in sports unless the injury is appropriately immobilized in a cast or splint. Wrist injuries do have the potential for delayed or failed healing despite appropriate initial

Table 1 Types of Wrist Injuries

Acute	*Chronic*
Distal radius fracture	Ganglion cyst
Scaphoid fracture	Intersection syndrome
Wrist ligament sprain/tear	Kienböck disease
Hook of hamate fracture	de Quervain tenosynovitis
Triangular fibrocartilage complex (TFCC) tear	Dorsal pole of lunate and distal radius impingement (gymnasts)
Distal radioulnar joint instability	Tendinopathy (flexor carpi ulnaris, extensor carpi ulnaris)
Scapholunate dissociation	Posterior interosseous nerve entrapment
Carpal bone dislocation	Inflammatory arthropathy
Carpal tunnel syndrome	Degenerative joint disease
	Nonunion of scaphoid fracture

treatment, requiring subsequent surgical intervention. Therefore, early referral to an orthopedic or hand surgeon is recommended for follow-up. Another consideration in determining when an athlete is ready to return to sports is the safety of the injured athlete as well as the other participants. If an athlete is considering returning to sports wearing a protective device, permission should be obtained from trainers, coaches, and officials.

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See also Colles Fracture; Musculoskeletal Tests, Hand and Wrist; Wrist Dislocation; Wrist Fracture; Wrist Sprain; Wrist Tendinopathy

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Wrist Sprain

A *sprain* is an injury to a ligament. Ligaments are a type of tissue that connects bones to bones and provides stability to joints. One may think of ligaments as analogous to ropes. *Sprain* comes from the French word *espraindre,* which means "to wring." A wrist sprain is an injury to the ligaments of the wrist. Often, sprains occur from falls or sports-related injuries that involve forcibly bending the wrist backward (hyperextension) or excessive pressure through the long axis of the joint (axial loading), with subsequent damage to the ligaments of the wrist joint.

Anatomy

The wrist comprises many different types of structures, including eight small bones (called carpal bones), multiple ligaments, cartilage—a firm covering of the bones (e.g., the tip of your nose), and specific junctions with the bones of the hand (metacarpals) and forearm (radius, ulna). The joint where the radius and ulna are connected near the hand is called the distal radial ulnar joint (DRUJ). This joint is particularly susceptible to injury during falls.

Several structures in the wrist deserve particular mention, including the triangular fibrocartilage complex (TFCC). The TFCC is a special type of tissue (a mix between fibrous tissue and cartilage) that absorbs stress during axial loading of the wrist and limits lateral movement of the carpal bones. Throwing a "jab" or "punch" in boxing, for example, would be axially loading the wrist joint. This special cartilage (TFCC) also stabilizes the DRUJ.

There are two types of ligaments in the wrist—extrinsic, which connect the radius and ulna to the carpal bones, and intrinsic, which connect the carpal bones to each other.

Extrinsic ligaments have two components, *volar*—the palmar or underside of the wrist and hand, and *dorsal*—the backside (knuckle side) of the wrist and hand.

The volar radiocarpal ligaments are stronger and thicker than the dorsal and so provide the majority of motion stability in the wrist. The most important ligament of this group is the radioscaphocapitate, which attaches the radius (forearm bone) to the scaphoid and capitate (carpal bones). Intrinsic ligaments are also called interosseous ligaments. They originate on the carpal bones and are within the capsule of the wrist.

The most common ligament indicated in wrist sprains is the scapholunate, which is an intrinsic ligament between the scaphoid and lunate bones. It comprises dorsal collagen bundles that provide a structure that lends to its superior stability. Another important interosseous ligament is the lunotriquetral, connecting the lunate and triquetrium carpal bones.

Classification of Injuries

Sprains are classified based on severity, ranging from mild to moderate to severe injury. Typically, Grade I sprains represent the least amount of injury—a stretching of the ligament fibers—and result in minimal or no loss of function at that joint. Grade II sprains usually equate to a partial tearing of the ligament. This may be observed by increased swelling and pain of the joint along with moderate dysfunction. The most serious of wrist sprains would be a complete tear of the ligament, a Grade III sprain. This results in an unstable joint and requires immobilization (splinting) and often referral to a specialist.

Injury Setting and Symptoms

Wrist sprains occur in many settings and due to a variety of reasons, including direct injury, chronic repetitive trauma and loading activities, or falls and sports-related injuries. Sprains are more common in adults than in children due to the different anatomy of the developing bones in children. In younger populations, similar injuries more often produce fractures of the immature bone rather than damage to the ligaments. Commonly, skiing, skating, snowboarding, and inline skating are sports associated with wrist sprains, but they can occur in any contact or noncontact sports under certain conditions. At times, specific wrist injuries are classified as *f*alls *o*n an *o*ut*s*tretched *h*and (FOOSH), such as fractures of the scaphoid bone or disruption of the scapholunate ligament.

Patients with wrist sprains may report feeling a tear or hearing a pop during the event. Areas of the wrist or hand may swell, demonstrate bruising, or be painful to touch. Patients have difficulty and pain with movement of the wrist. Wrist and hand anatomy is intricate, and diagnosing an injury may present a difficult task, so an evaluation should include a detailed history, a careful physical exam, and often radiographs. The exam should consist of general inspection, a neurovascular evaluation, palpation of bony prominences and ligaments, and assessment of joint range of motion and stability.

Treatment

Sprains usually heal completely within 4 to 6 weeks. Conservative treatment involves splinting in a neutral position with either a brace or a compressive elastic wrap, rest from painful activity, application of ice packs, and taking nonsteroidal anti-inflammatory drugs (NSAIDs) to reduce swelling and for pain relief. After a period of immobilization and before returning to full activity, patients should exercise to improve wrist range of motion and strength. This may include work with a resistance band or weights for wrist extension, flexion, and ulnar and radial deviation (ulnar deviation: side movement in the direction of the little finger; radial deviation: side movement in the direction of the thumb).

Grade III sprains or complete tears of ligaments may require surgical correction and repair. These injuries represent unstable joints, and the wrist must be immobilized at the discovery of injury to prevent additional or more serious injury.

While most wrist sprains heal with conservative therapy and without other intervention, some important conditions must not be missed due to varying treatments and risk of adverse events. These include injury to the TFCC, carpal bone dislocation (displacement), DRUJ, or any fracture of the carpal bones or forearm bones (radius or ulna).

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See also Wrist Fracture; Wrist Injuries; Wrist Tendinopathy

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Wrist Tendinopathy

Overuse wrist tendon injury, or *tendinopathy,* occurs regularly in athletes participating in sports with repetitive wrist and hand movement. Unlike more proximal tendinopathies (e.g., rotator cuff), which are typically degenerative and noninflammatory, symptoms from wrist tendinopathy frequently involve inflammation of the outer tendon sheath, known as paratenonitis. The most common wrist tendinopathies in athletes involve the dorsal/extensor aspect of the wrist, such as de Quervain disease, intersection syndrome, and extensor carpi ulnaris (ECU) paratenonitis.

Risk factors for athletic wrist tendinopathy include muscle weakness or imbalance, overuse from training load, improper technique or equipment, and inadequate rest. The accurate diagnosis of wrist tendinopathy requires skilled history taking and physical examination, and advanced imaging is infrequently necessary. Treatment of inflammatory tendinopathy of the wrist includes rest, noninvasive anti-inflammatory modalities (e.g., ice, anti-inflammatory medications), risk factor modification, and occasional local corticosteroid injection. With an accurate diagnosis and a treatment plan customized for the athlete, the sport, and the severity of the condition, most athletes with wrist tendinopathy return to their sport quickly and very rarely have long-term limitation.

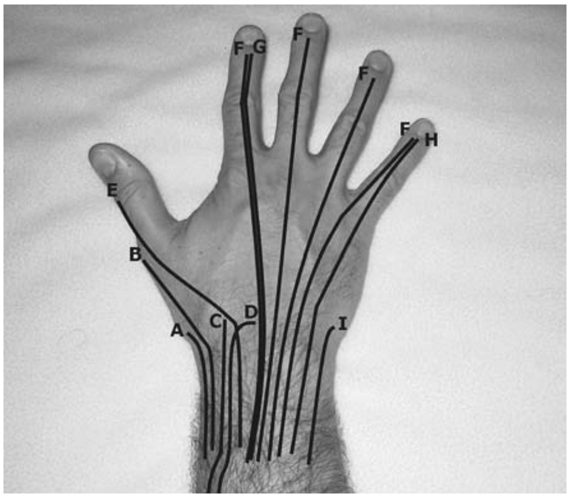
Anatomy

Tendons consist of longitudinally oriented, closely grouped collagen bundles with an outer covering called the paratenon. In areas such as the wrist, where tendons bend at acute angles over bone, the paratenon is thicker and lined with synovium and is called a tendon sheath. The synovium of the tendon sheath both provides mechanical resistance to shearing forces and produces synovial fluid, lubricating the tendon to decrease frictional injury.

Wrist tendons are divided into extensor tendons, which run over the dorsal aspect of the wrist, and flexor tendons, which run over the volar/palmar aspect of the wrist. The side of the wrist closest to the radius (and thumb) is referred to as the radial aspect of the wrist, and that closest to the ulna (and fifth finger) is referred to as the ulnar aspect of the wrist. The relative anatomic course of each of these wrist and finger tendons is represented in Figure 1 (extensors) and Figure 2 (flexors). The dorsal/extensor wrist is divided into six compartments, numbered from the radial to ulnar aspects, the first two of which are frequently involved in athletic wrist tendinopathies. The first dorsal compartment consists of the abductor pollicis longus (APL) and extensor pollicis brevis (EPB) tendons. The second dorsal compartment includes both extensor carpi radialis brevis (ECRB) and extensor carpi radialis longus (ECRL) tendons.

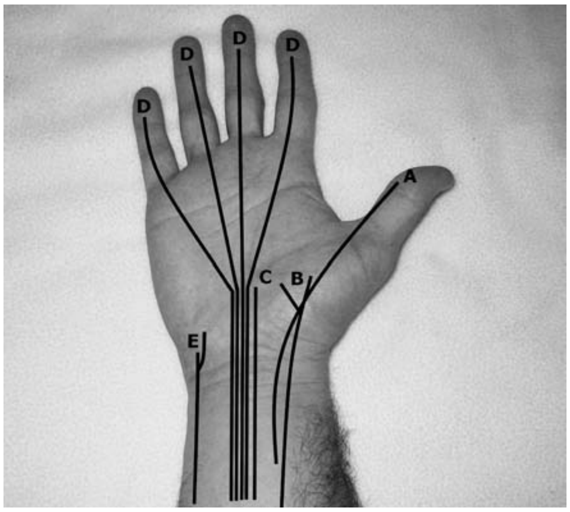
Pathology

Tendinopathy is a broad term that includes tendinitis, tendinosis, and paratenonitis. *Tendinitis*



Tendons of the dorsal aspect of the wrist: (a) abductor pollicis longus, (b) extensor pollicis brevis, (c) extensor carpi radialis longus, (d) extensor carpi radialis brevis, (e) extensor pollicis longus, (f) extensor digitorum, (g) extensor indicis, (h) extensor digiti minimi, and (i) extensor carpi ulnaris

Source: Photo courtesy of Jeffrey D. Smithers, M.D.



Tendons of the volar aspect of the wrist: (a) flexor pollicis longus, (b) flexor carpi radialis, (c) palmaris longus, (d) flexor digitorum (superficialis and profundus), and (e) flexor carpi ulnaris

Source: Photo courtesy of Jeffrey D. Smithers, M.D.

refers to inflammation of the tendon substance and rarely occurs without the presence of underlying degenerative tendon change, or *tendinosis*. *Paratenonitis,* or alternatively *tenosynovitis,* involves inflammation of the paratenon/tendon sheath, can occur alone or in combination with tendinosis, and constitutes the majority of wrist tendinopathy. However, elite and older athletes also often have some component of underlying tendinosis contributing to their symptoms.

De Quervain disease and intersection syndrome are the two most common athletic wrist tendinopathies. De Quervain disease is a paratenonitis of the tendons in the first dorsal compartment. Intersection syndrome, while not a classic paratenonitis, represents inflammation of the crossover area where the musculotendinous junctions of the first dorsal compartment meet with the tendons of the second dorsal wrist compartments. Less common wrist tendinopathies in sports include the separate syndromes of ECU and FCU (flexor carpi ulnaris) paratenonitis along with the infrequent flexor carpi radialis (FCR) paratenonitis and carpal tunnel syndrome from paratenonitis of the digital flexor tendons.

Causes

Wrist tendinopathy in athletes results from chronic microtrauma due to tendon overuse. While athlete ageing and tendon underuse can contribute to degenerative tendon changes, most wrist tendinopathies are caused by a combination of numerous factors, the most important being excessive repetition of wrist and hand motion. Such motion is required in many sports, including racquet sports (tennis, squash), golf, baseball, volleyball, gymnastics, rowing, and rock climbing. Other factors contributing to wrist tendinopathy include muscle imbalance or weakness, improper technique (e.g., excessive wrist radial deviation on the tennis forehand), improper equipment (e.g., size of the bat or racquet handle), and inadequate recovery time.

Causative sports for specific wrist tendinopathies are those that involve motions isolating the involved tendons. For example, de Quervain disease affects two tendons exerting their action on the thumb and is common in sports that require strong or repetitive thumb motion, such as racquet (tennis) and other hand grip sports (rowing and golf). Intersection syndrome involves tendons that act on both the thumb and the radial aspect of the wrist, is caused by repetitive wrist extension in radial deviation, and is encountered in many of the previously mentioned sports, along with weight lifting and downhill skiing. ECU paratenonitis and tendinosis occur from excessive wrist extension in ulnar deviation and are seen especially in racquet sports, golf, and rowing. FCU paratenonitis is also common among golf and racquet sport athletes.

Clinical Evaluation

History

Suspicion for wrist tendinopathy in an athlete generally stems from pain over the involved tendon(s). Pain from paratenonitis is typically constant and proportional to activity level and can be seen in athletes of all ages. Patients with paratenonitis usually report a recent increase in the duration or intensity of their sports activity and often note accompanying swelling, stiffness, and wrist "squeaking." Alternatively, athletes with tendinosis will complain of more intermittent pain and will usually have a remote history of overuse. Patients with tendinosis will also typically complain of pain that starts during the warm-up phase, decreases during activity, and increases during the cooldown and recovery phases. Finally, patients with tendinosis will describe a course of pain that begins as sharp and intense and becomes more dull and achy over time. Because paratenonitis can be seen in combination with tendinosis, symptoms from both processes can co-occur.

Accompanying symptoms such as paresthesia, weakness, radiation of pain, blunt trauma, fever, and overlying skin changes should be ruled out in the athlete with tendon pain. The presence of these symptoms should prompt consideration of more extensive differential diagnosis and work-up. Of note, rheumatologic conditions such as rheumatoid arthritis affect the synovium, causing both arthritis and paratenonitis, and should be suspected in an athlete with recurrent or diffuse paratenonitis.

Physical Examination

A thorough examination of the affected forearm, wrist, and hand along with comparison with the nonaffected side is necessary in evaluating athletes with suspected wrist tendinopathy. They will have pain to tendon palpation, especially under tension with manual muscle testing. As with most inflammatory conditions, patients with wrist paratenonitis will have associated palpable swelling and increased temperature over the affected area of the tendon. Patients with wrist paratenonitis can also have crepitus and occasional catching with passive movement of the involved joint, as in passively flexing and extending the wrist in ulnar deviation to evaluate ECU paratenonitis. Finally, the athlete will often have pain with the tendon in full stretch, such as the Finkelstein maneuver, in which the patient is asked to make a clenched fist about the adducted thumb and the examiner subsequently places the patient's wrist in ulnar deviation. Pain over the radial styloid (distal radius) with this maneuver is highly specific for de Quervain disease.

Imaging

Clinical assessment with history and physical examination is usually sufficient for accurate diagnosis and classification of wrist tendinopathy. Plain radiographs in tendinopathy are routinely negative, and advanced imaging is rarely required. However, in cases recalcitrant to initial therapy or where more significant tendon disruption is suspected, magnetic resonance imaging (MRI) and ultrasound can serve as helpful adjuncts. On the MRI scan, paratenonitis demonstrates increased (fluid) signal in the tendon sheath on T2 and STIR (short inversion time inversion recovery) sequences, whereas tendinosis shows less uniform increased intratendinous signal on the same sequences. Ultrasound examination of paratenonitis demonstrates anechoic signal (representing fluid) in the surrounding tendon sheath, and in tendinosis, it shows hypoechoic intratendinous regions.

Treatment

The mainstay of wrist tendinopathy treatment is conservative therapy relying on relative rest, ice, analgesics (e.g., oral or topical nonsteroidal medications), physical therapy, and short courses of wrist bracing or splinting, to include thumb spica immobilization in cases of de Quervain disease. In paratenonitis, use of topical (e.g., iontophoresis) or systemic corticosteroid treatment can be beneficial, and local injections of topical anesthetic and corticosteroid into the tendon sheath by skilled hands are often effective in confirming the diagnosis and treating the condition. In cases with underlying tendinosis, anti-inflammatory treatments do not treat the underlying degenerative pathology and cannot prevent recurrence. The most widely accepted treatment modality for tendinosis is eccentric muscle strengthening of the affected muscle-tendon unit. In all tendinopathies, adjustment of the underlying modifiable risk factors, such as errors in technique, training schedule, or equipment, must always be addressed for adequate treatment and prevention of recurrence. In rare cases where the athlete's wrist tendinopathy does not respond to conservative treatment, surgical release of the tendon sheath or debridement of the degenerative tendon may be indicated.

Conclusion

Wrist tendinopathy from tendon overuse commonly affects athletes participating in tennis, golf, and other sports requiring repetitive wrist and hand motion. Inflammation of the tendon sheath surrounding the tendon, or paratenonitis, is the most common underlying pathology in these cases and often responds to conservative therapy with relative rest, analgesics, and anti-inflammatory modalities without long-term sequelae.

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See also Colles Fracture; Musculoskeletal Tests, Hand and Wrist; Wrist Dislocation; Wrist Fracture; Wrist Sprain

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Y

Young Athlete

Youth participation in sports has increased dramatically in recent years. Children are becoming involved at younger and younger ages and are training with increasing intensity. Understanding their unique needs with respect to injury patterns, changing body habits, and psychological development is key to dealing with the child athlete. A sensible approach to training that takes into consideration skill level and motivation, as well as physical and emotional development, will help prevent injuries and promote enjoyment of the sport. For the child who becomes involved in competition, acquisition of skills and fitness must be balanced with avoidance of overtraining. It is important to have some knowledge of the types of injuries our young athletes sustain and an understanding of the prevention and rehabilitation of these injuries. Finally, the most influential people in the child athlete's life, coaches and parents, need to help the child keep winning in perspective.

Uniqueness of the Child Athlete

Growth and development are the most important features that distinguish young athletes from adults. The changing mechanical properties of growing bones and tissues give rise to maturation-related injuries. Bone growth occurs first, followed by a secondary lengthening of muscle–tendon units and ligaments. Many experts feel that during a growth spurt, there is a relative decrease in flexibility before the soft tissues catch up with bone growth. This decrease in flexibility places the child at risk for injuries such as Osgood-Schlatter apophysitis or patellofemoral pain. The imbalances in muscle strength and flexibility that occur during these periods of growth are risk factors for both sudden (acute) injuries and overuse injuries. Growing bones themselves are weakened because bone matrix formation and mineralization do not occur at the same rate. As a result, children's bones are less dense than those of adults.

The types of bony injuries sustained by children are quite different from adult injuries. For example, a similar mechanism of injury may produce a displaced or comminuted fracture in an adult bone, but it may only cause bending (plastic deformation) of the softer bone of the child athlete. The inherently weak growth plate (physis) is involved in 30% of all fractures of the long bones of children. During different stages of development, the relative strength of the physes changes, with the time of the greatest vulnerability to injury being the onset of the adolescent growth spurt. At such times, if stressed, the musculoskeletal system will break down at the growth plates before the adjacent ligaments tear. In prepubescence and again in late pubescence after growth has slowed, the physes may actually be stronger than the adjacent ligaments; therefore, true sprains are more likely to occur than injuries to the physes.

The main concern with growth plate injuries is the potential for altered growth. This also depends on the child's stage of development. For example, repetitive microtrauma to the wrists in gymnasts during early puberty may result in a temporary decrease in growth of the growth plate at the lower portion of the forearm (the distal radial physis). Normal growth is restored once the trauma stops. The same injury to a midpubertal gymnast may result in permanent loss of growth.

Other areas of growth tissue occur at the tendon insertions of large muscle groups. These sites are known as apophyses and are subject to injuries unique to the growing athlete. A common site of apophyseal injury is the insertion of the patellar tendon into the top of the shin (tibial tubercle). Repetitive stress at this site can cause either apophysitis or avulsion fracture. Apophyseal injuries will be discussed later in this entry. It is important to remember that the tissues of the young athlete are in transition, which has a great bearing on the types of injuries sustained.

The child athlete differs from the adult in other ways as well. The response of the cardiovascular system and the body's control of temperature (thermoregulation) to exercise in children is different from that in adults. Thermoregulation will be discussed in greater detail later. Regarding cardiovascular differences, children generally use more oxygen for a given activity and rely on anaerobic metabolism less than adults do during exercise. They tend to have higher heart rates and pump less blood from the heart with each beat (lower cardiac stroke volume) as well. This can affect how well the child tolerates physical activity. In addition, reaction time decreases as the child matures.

With increasing strength and endurance, particularly in the latter half of childhood, speed of movements and general skills increase. Thus, the innate tools that the child athlete has at his or her disposal vary with physical maturation. This should be kept in mind when setting goals for the child in sports.

Thermoregulation: Exercise in the Heat

Approximately 80% of energy released during exercise is in the form of heat. If the mechanisms for heat loss are not functioning properly, the athlete may experience a 1 °C increase in body temperature per 5 minutes of activity. If this is allowed to continue, it would be potentially fatal within 20 minutes. Mild dehydration, as little as 1.2%, may make it even more difficult to control body temperature. Once water deficits are greater than 3%, there is a significant risk of heat illness. Heat-related illnesses include a spectrum of conditions ranging from heat cramps, which are painful, sustained muscle contractions, to life-threatening heat stroke.

Uniqueness of Children

The thermoregulatory mechanisms in children are slightly different from those in adults. Compared with adults, children produce more heat per kilogram (kg) while walking and running. They begin to sweat at a higher core temperature and sweat less per square meter. They have a lower cardiac output at a given metabolic level and less blood flow to the skin for removal of heat by convection. Their larger body surface area per kilogram results in increased heat exchange between the environment and the skin, causing greater heat stress. Their thermoregulatory impairment from dehydration is also greater.

Children are slower than adults to acclimatize to heat. Acclimatization involves physiologic changes that increase tolerance to exercise in the heat. This adaptation is influenced by age, duration of exposure to heat, rate of body heat production, severity of environmental stress, and the preexisting level of conditioning of the athlete. These differences in thermoregulation place the child athlete at increased risk of heat illness, especially in extreme heat.

Prevention of Heat Illness

Prevention of heat illness addresses environmental conditions, hydration, clothing, conditioning, and acclimatization. Activity should be modified in the face of high ambient temperature or humidity. For temperatures less than 19 °C (67 °F), the players most susceptible to heat stress should be under close observation. Unlimited supplies of drinking water should be available on the field, and athletes should be encouraged to take fluids when ambient temperatures are between 19 and 25 °C (67 and 77 °F). Water breaks should be scheduled every 20 to 25 minutes. For temperatures above 25 °C (77 °F), practice sessions should be reduced and, if possible, scheduled for early morning or late afternoon. Susceptible players, such as those with a history of heat illness, should be withheld from participation. At any temperature, if relative humidity is greater than 95%, activity should be modified as per the requirements for temperatures >25 °C.

Athletes may lose 2% to 3% body weight before thirst develops, at which point performance is already impaired. To ensure adequate hydration, adolescent athletes should be encouraged to drink 235 milliliters (ml; 8 ounces [oz]) of water 10 to 15 minutes prior to workout and 235 to 350 ml (8–12 oz) at 20- to 30-minute intervals throughout the practice. Younger, smaller athletes will need slightly less than this amount (approximately 150 ml of cold tap water every 30 minutes for a 40-kg child). After workout, drinking to quench thirst will replenish only one third to one half of fluid losses; therefore, athletes should weigh themselves before and after workout (without clothes) and should drink 1 liter/kg lost (2 cups/pound). Plain water is adequate for most activities of young athletes.

Appropriate clothing for training in the heat is lightweight, single layer, and absorbent. As much skin as possible should be exposed to air, and sweat-saturated articles of clothing should be changed. If helmets are worn, they should be removed between drills, because a significant proportion of heat loss occurs via the head. Sauna suits for weight reduction should never be permitted.

Athletes should start the season as physically fit as possible. A preseason conditioning program will give the child a good baseline fitness level, which will not only decrease the risk of heat illness but also help prevent other problems such as overuse injuries. An attempt should be made to acclimatize the athlete before beginning a strenuous program or before travel to a warm climate.

Common Injuries Associated With the Child Athlete

Several injuries occur more frequently, or in some cases uniquely, in the skeletally immature athlete. These injuries can be divided into either acute or overuse types. Acute bone injuries encountered exclusively in the child athlete include *growth plate* (physeal) *injuries* and *apophyseal avulsion fractures,* which occur when large tendons pull off (avulse) fragments of bone and growth cartilage at the sites where tendons and bones join. Other fractures seen in children (torus, greenstick, plastic deformation) occur because of a lesser degree of mineralization and thinner cortices than in adult bones. There are also several overuse injuries that are seen primarily in young athletes. The most common of these are discussed in this section.

Acute Injuries

Growth Plate Injuries

At certain times during development, growth plates are weaker than the surrounding soft tissues; therefore, when a joint is placed under abnormal stress, such as a sudden, forceful inversion of the ankle, the result is a fracture through the growth plate. This is accompanied by swelling and tenderness on the outer aspect of the ankle. There may be some tenderness over the ligaments, but if there is bony tenderness over the lateral ankle, it is likely to be a growth plate injury. This relative weakness of the physes is maximum at the onset of the growth spurt. Immediate management includes ice, elevation, and compression. Immobilization and crutches may be necessary for pain control. Early institution of physical therapy will restore function and help prevent reinjury. It is possible for young athletes to sprain ligaments rather than injure physes, particularly adolescents nearing physical maturity and prepubescent athletes.

Avulsion Fractures

Children with open physes also have apophyses at the insertion of large tendons into bone. Like growth plates, these cartilage structures are subject to injury, particularly during rapid growth. The most common acute injury to the apophysis is an *avulsion fracture*. Avulsion fractures are typically seen in 14- to 17-year-old males. These occur frequently around the pelvis, into which several large muscles insert. These athletes will complain of severe pain at the affected site and inability to continue activities. Pain will worsen with contraction of the muscle responsible for the avulsion injury. Athletes should apply ice and use crutches during the acute phase. Relative rest with early institution of physical therapy will hasten the recovery. Full range of motion and normal strength should be regained prior to return to sports participation.

Overuse Injuries

Overuse injuries result from repetitive microtrauma to bones and soft tissue. Growth is a risk factor for overuse injury in the young athlete. Growth cartilage is inherently weak when compared with the adjacent bone and is unable to withstand excessive repetitive stress. Many experts feel that flexibility decreases with growth, as muscles and tendons are stretched by the growing bones. Muscle tightness is a well-known risk factor for overuse injury among athletes of all ages. Training error is another recognized risk factor for overuse injury. Examples of training errors include sudden increases in training intensity or duration. These errors are encountered frequently in the context of summer sport camps, where children may increase their participation in a given physical activity from a few hours per week to a few hours or more each day.

Little League Elbow

Little League elbow refers to a number of different conditions that cause pain about the elbow. The forces generated during throwing result in valgus stress to the elbow, with compression on the outer aspect and tension on the inner aspect of the joint. Specific diagnoses can include medial epicondyle apophysitis, overgrowth of the radial head, osteochondritis dissecans of the radial head, and premature closure of the radial growth plate at the elbow. If there is swelling and decreased range of motion in the joint, there may be a problem with the cartilage and bone of the joint or there may be a loose body in the elbow. The child should be referred to a physician for evaluation, and further pitching should be avoided until an assessment has been done. Management includes avoidance of aggravating activities and initiation of physical therapy for range of motion followed by strength exercises. Once pain has resolved, range of motion is full, and careful evaluation of the throwing technique to correct errors that may have contributed to the injury is done, *gradual* return to play is possible. If the number of throws per week is limited to not more than 300, it may help prevent some of these injuries.

Osgood-Schlatter Apophysitis

Osgood-Schlatter apophysitis is a painful response to repetitive stress at the patellar tendon/tibial tubercle junction. Injury of the apophysis results in pain with jumping and running and tenderness to touch. Swelling may be seen over the tibial tubercle on the upper portion of the lower leg. This condition is most often observed in young athletes who have patellar maltracking or who have recently undergone a growth spurt. In the latter situation, muscles about the knee become very tight, placing added stress on the extensor mechanism. A similar stress injury (Sinding-Larsen-Johansson syndrome) occurs at the lower pole of the patella. The presentation of Sinding-Larsen-Johansson syndrome is similar to that of Osgood-Schlatter, except that the point of maximal tenderness is the lower portion of the patella. Reassurance is the first part of treatment for Osgood-Schlatter apophysitis. Athletes and their parents need to know that this condition will resolve when growth is complete. In the meantime, attempts must be made to decrease pain and secondary inflammation and to prevent recurrence. The child should be advised to stop any jumping or running activities until the pain and swelling have subsided. Application of ice three or four times per day while the symptoms are severe may be enough to reduce the pain. Nonsteroidal anti-inflammatory drugs, or NSAIDs, are of limited use other than as analgesics, unless there is significant secondary soft tissue swelling present. A home exercise program must begin immediately to work on hamstring and quadriceps stretching. When the pain has decreased, strengthening of these muscles can begin. The athlete is permitted to return to full activity only when jumping and running are pain free. A strap brace may be placed over the patellar tendon to reduce the pull of the quadriceps on the tibial tubercle. A knee pad to protect the tibial tubercle from direct trauma may reduce incidence of flare-ups. This condition can recur and occasionally can lead to avulsion fractures of the tibial tubercle.

Osteochondritis Dissecans

Osteochondritis dissecans (OCD) is an injury that affects a localized area of cartilage on the joint surface (articular cartilage) of bone, along with a small portion of underlying (subchondral) bone. Although the exact cause of this condition is not entirely clear, there appears to be some localized insufficiency of the blood supply to the bone, likely exacerbated by repetitive trauma or compressive forces. As the bone loses its blood supply, the overlying articular cartilage and subchondral bone may become unstable. In more severe cases, the bone and cartilage fragment becomes a loose body in the joint. OCD in the knee usually occurs on the inner aspect of the lower end of the thighbone (femur). This condition is also seen in the outer aspect of the elbow in Little League elbow and in the ankle (talus). A child with OCD of the knee may present with intermittent joint swelling, pain, and limited range of motion. Management depends on the severity of the OCD and the maturity of the child. In a growing child with intact cartilage overlying the bony defect, full range of motion, and no locking, nonsurgical treatment may be adequate. The child is restricted from impact activities such as jumping and running, and early physical therapy is initiated to maintain or regain range of motion. Other treatments may include limitation on weight bearing or use of bracing. Resistive weight training should be withheld for 6 to 12 weeks until bone healing occurs. It may be as long as 6 to 12 months before the athlete can resume full activities. Arthroscopic surgery may be necessary in the presence of mechanical symptoms such as locking, if magnetic resonance imaging (MRI) suggests an unstable fragment, or if more conservative treatment does not result in healing after 3 to 6 months.

Sever Apophysitis

Sever apophysitis is an injury to the calcaneal apophysis that results in tenderness at the insertion site of the Achilles tendon in the heel. Children will usually present with posterior heel pain after activity. The condition occurs in both feet in two thirds of cases and typically occurs between 7 and 14 years of age. On examination, the most tender point is the back of the heel at the Achilles tendon insertion. There may be pain with passive stretching of the calf muscles or with active plantarflexion of the ankle (downward). Squeezing the heel (squeeze test) is usually painful. To unload the painful heel, weight bearing and gait may be altered. This may result in pain and tenderness of the Achilles tendon or under the arch of the foot, clinically suggestive of Achilles tendinosis or plantar fasciitis. Treatment includes heel cups to decrease stress on the apophysis, cessation of all painful activities, and institution of physical therapy. The therapy is aimed at reducing secondary inflammation through application of ice, as well as increasing the flexibility and strength of the calf muscles. When the pain has subsided, the athlete can increase physical activity as long as the pain does not recur.

Spondylolysis

Spondylolysis is a stress fracture of the pars interarticularis, which is one of the posterior elements of the spine. This injury is most commonly encountered in sports that require repetitive extension of the spine, such as gymnastics, figure skating, and ballet. Football and hockey players may also develop this injury from the repetitive stress of sled training or body checking, respectively. The athlete will complain of low back pain with extension movements of the spine. The athlete may note tightness of the hamstrings on the affected side. On examination, there is often some degree of muscle spasm alongside the defect in the lower back. Provocative tests such as extension of the spine (arching backward) will reproduce the symptoms. There will be a relative tightness of the hamstrings on the affected side. When dealing with gymnasts and dancers, it is important to remember that they are usually extremely flexible; therefore, left and right asymmetry should be noted.

Plain X-rays may show the fracture, but a special bone scan, SPECT (single-photon emission computed tomography), will be able to definitively diagnose the lesion. Treatment involves cessation of the offending activities. A rigid, custom polypropylene brace is often used to limit extension. The brace is worn for 23 hours a day, with 1 hour out for physical therapy and showering. Once the athlete is painfree in the brace, return to modified activity is allowed. Duration of bracing is generally 6 months to allow for bony healing. Many athletes are able to return to their sport while wearing the brace.

"It Is Not Whether You Win or Lose . . . "

It has been shown that children have a much greater likelihood of dropping out of sports where the greatest emphasis is on winning. It is easy for the child athlete to begin to equate winning with success and losing with failure. Fear of failure places an enormous amount of stress on the child athlete. If a child feels that his or her "success" depends on a win, then every competitive situation becomes even more stressful and every loss adversely affects self-worth. Winning is an important goal in competitive sports, but it needs to be kept in a healthy perspective. While striving to win, the sense of success should come from putting out maximal effort. Young athletes should feel that even though they make mistakes or lose games, as long as they are trying their best, their parents and coaches will approve. This will greatly enhance the child's enjoyment of the sport, making continued participation much more likely.

Prevention Techniques

When discussing prevention in sports, one must differentiate between physical and psychological injury. The physical injuries discussed in this entry include overuse and acute trauma, as well as heat illness. Prevention of overuse injuries involves addressing risk factors before they become problematic. Preparticipation physical examinations can identify muscle imbalances and other physical factors that may predispose the athlete to injury. Preseason conditioning can reduce the risk of injury to muscles and tendons. Athletes should be educated regarding specific preventative techniques such as stretching muscles when warm and aggressively working on flexibility during growth spurts. To allow tissues to adapt to increasing work loads, training should not increase more than 10% per week. Prevention of acute injuries involves ensuring adequacy of equipment (e.g., football helmets) and striving to ensure that young athletes are matched up based on size and maturation rather than age. Rules that are meant to minimize serious trauma (e.g., no spear tackling in football) should be adhered to. Prevention of heat illness was covered earlier in this entry.

Prevention of psychological injuries is an important part of dealing with young athletes. Psychological stress occurs when athletes perceive that the demands placed on them exceed their skills. If failure is perceived as catastrophic, the stress on the athlete increases significantly. If personal value becomes dependent on success, this also adds to stress. As a result, if stress levels become too high for the athlete to cope with, he or she may withdraw from sports. If training continues, the child may develop physical symptoms such as headache or abdominal pain as a direct result of the stress or as a mechanism to avoid participation. Such situations can be avoided by addressing the causes of stress. De-emphasizing winning can significantly reduce stress. Coaches play a key role in reducing stress among athletes by enhancing enjoyment of the sport. They can provide immediate reinforcement for good plays and good efforts. Correcting errors should be done in a positive way by explaining how correct techniques will be beneficial. Coaches should not emphasize the errors that the young athlete has made. Mistakes should never be met with disapproval or yelling.

Parent-induced stress can be difficult to address. This occurs in situations where the child becomes an extension of the parents, who want their little athlete to either follow in their footsteps ("star" athlete parents) or succeed where they have fallen short. The following guidelines for parents may be helpful in these situations.

1. Parents should remain seated in the spectator area during the contest.
2. Parents should not yell instructions or criticism to their children.
3. Parents should make no derogatory comments to players, parents of the opposing team, officials, or league administrators.
4. Parents should not interfere with their children's coach. They must be willing to relinquish the responsibility for their child to the coach for the duration of the contest.

Conclusion

Because of the many benefits, both physical and mental, of sports participation children need to be encouraged to become involved. Ideally, the sport should choose the child, which means that the suitability of the child for a particular sport is considered before he or she begins. For example, a child with pes cavus (high-arched feet) may be better suited to swimming than running; however, in most cases, the child is already involved in his or her sport when problems arise. It is the role of the coach, parent, and physician to monitor the effects of the activity on the child. Intervention before problems arise can be accomplished by addressing risk factors early. When injuries occur, adequate rehabilitation will help prevent recurrence. The concept of "winning at all costs" should not be ingrained in the child athlete; rather, enjoyment of the sport should be the primary goal. It is important to remember that the elite young gymnast is not only an athlete but a child as well.

Merrilee Zetaruk

See also Apophysitis; Cardiovascular and Respiratory Anatomy and Physiology: Responses to Exercise; Juvenile Osteochondritis Dissecans of the Knee; Osgood-Schlatter Disease; Overtraining; Spondylolysis and Spondylolisthesis; Temperature and Humidity, Effects on Exercise

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Youth Fitness

Fitness is a state of well-being that allows the body to function efficiently and effectively during school, work, leisure, and sports activities. In general, there are two main categories of fitness. *Health-related fitness* is said to include cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition, whereas *skill-related fitness* components include agility, coordination, reaction time, balance, speed, and power. Both are associated with numerous physiological and psychological benefits during childhood and adolescence. In addition, positive behaviors that are acquired during the school-age years are likely to be carried over into adulthood. Thus, youth who enjoy fitness activities and learn how to live a physically active life are more likely to become active, healthy adults.

Current Health and Fitness Status

Although youth tend to be more active than adults, nowadays fewer children and adolescents walk or ride their bicycles to school, and sedentary pursuits such as television viewing and "surfing" the Internet have decreased youngsters' need to move. A majority of children do not participate in any organized physical activity during nonschool hours, and physical education and recess periods are unfortunately viewed as expendable in some school districts. It is becoming more apparent that the lack of daily physical activity along with the greater accessibility to energy-dense foods is contributing to the increasing prevalence of obesity among school-age youth.

These trends have significant implications for the present and future health of children and adolescents, given the increased prevalence of cardiovascular disease risk factors and obesity-related comorbidities such as Type 2 diabetes, heart disease, and cancer. If current trends continue, the health-related consequences of physical inactivity and childhood obesity will likely pose an unprecedented burden on youth, their families, and our health care system. As a result, the promotion of safe, effective, and enjoyable fitness activities for children and adolescents with different needs, goals, and abilities has become a major public health issue.

General Youth Fitness Guidelines

Children and adolescents should be encouraged to be physically active as part of play, recreation, sports, and school activities. Researchers and health care providers recommend that school-age youth participate daily in 60 minutes or more of moderate to vigorous physical activity that is developmentally appropriate, that is enjoyable, and that involves a variety of activities. This recommendation provides a reasonable standard that even sedentary boys and girls can achieve with a modest commitment to physical activity and support from their parents and schools. Youth can increase the amount of time they have for physical activity by reducing sedentary leisure pursuits such as television viewing, computer use, telephone conversations, and video games. Sedentary youth should gradually increase the amount of physical activity by about 10% per week until they reach the 60-minute goal.

Since youth will rarely perform prolonged periods of physical activity without rest or recovery, youth should be encouraged to accumulate their physical activity requirement throughout the day rather than perform a continuous bout of physical activity at a predetermined intensity. While continuous moderate-to-vigorous physical activity is not physiologically harmful, it is not the most appropriate method of exercise for youth, who tend to enjoy nonsustained activities or games. Watching children on a playground supports the premise that youth tend to have short bursts of physical activity followed by brief rest periods to recover and recharge. Participation in age-appropriate fitness activities is more likely to become a lifelong habit if youth experience success, gain confidence in their physical abilities, establish a base of general fitness, and become aware of the health benefits of physical activity.

Health- and Skill-Related Fitness Activities

Unlike most adult fitness programs that isolate fitness components, youth fitness programs should provide participants with the opportunity to improve both health- and skill-related components of fitness. While the components of health-related fitness relate specifically to health enhancement and disease prevention, skill-related components are necessary to perform daily activities as well as recreational pursuits and sports skills.

Health-Related Fitness Activities

While most youth can accumulate 60 minutes of daily physical activity, health-related activities including aerobic games, strength training, and flexibility exercises must be punctuated with brief rest periods. Stop-and-go games or circuit training activities that alternate higher-effort and lower-effort segments have proven to be effective. While the standard means of assessing aerobic exercise intensity in adults is heart rate monitoring, this type of assessment is problematic for healthy children, who have great difficulty finding and counting their pulse rate during exercise. Moreover, there is little need for healthy children to monitor their heart rate response because adult target heart rate formulas are inappropriate for youth under 16 years of age. Generally, simple observations may be sufficient for determining physical exertion during youth fitness activities.

Despite traditional concerns associated with youth strength training, research clearly demonstrates that strength training can be a safe, effective, and worthwhile activity for children and adolescents provided that age-appropriate training guidelines are followed. Although there is no scientific evidence to suggest that the risks and concerns associated with youth strength training are greater than those of other sports and recreational activities in which children and adolescents regularly participate, youth strength training programs must be competently supervised, properly instructed, and appropriately designed. In general, if a child is ready for participation in some type of sport activity (generally at age 7 or 8), then he or she may be ready to strength train. Different types of equipment, including free weights (e.g., barbells and dumbbells), child-size weight machines, elastic bands, medicine balls, and body weight exercises, have proven to be safe and effective for children and adolescents.

While flexibility is a well-recognized component of health-related fitness, long-held beliefs regarding the traditional practice of warm-up static stretching have been questioned. Research findings suggest that static stretching immediately before exercise has no significant effect on injury prevention and can have a negative influence on strength and power performance in children and adolescents. Children and adolescents should perform low- to moderate-intensity dynamic activities (e.g., walk, jog, hop, skip, and jump) during the warm-up period and static stretching exercises during the cooldown period. Because gains in flexibility are specific to the flexibility exercises performed at each joint, youth should perform a variety of static stretches for the upper body, lower body, and midsection. The cooldown may actually be the ideal time to perform static stretching exercises because the muscles are already warmed up and participants need to recover from the exercise session with less intense activities.

Skill-Related Fitness Activities

Most youth programs focus primarily on enhancing the health-related components of fitness and underemphasize the importance of developing skill-related fitness abilities that are characteristic of how children move and play. Games, activities, and exercises that involve skipping, hopping, twisting, kicking, and throwing can help youngsters develop the necessary prerequisite movement skills prior to facing the demands of more demanding fitness programs and sports training sessions. With competent instruction and quality practice time, children and adolescents can learn the skills needed for successful and enjoyable participation in recreational activities and organized sports.

Leadership and Instruction

The challenges associated with promoting youth fitness should be met with enthusiastic leadership, creative programming, and effective age-specific teaching strategies. A major objective of youth fitness programming is for physical activity to become a habitual part of children's lives and, if possible, persist into adulthood. With this objective in mind, parents, teachers, and youth coaches must strive to increase participants' self-confidence in their physical abilities. To achieve this objective, clear instructions should be provided so that participants can experience success and develop a sense of mastery of a specific skill. Thus, the focus of youth fitness programs should be on positive experiences instead of stressful competition in which most children fail.

Professionals should understand the uniqueness of childhood and adolescence and should genuinely appreciate the fact that youth are active in different ways and for different reasons compared with adults. Professionals who choose to work with children and adolescents need to relate to youth in a positive manner and understand how they think. Participation in a youth fitness program is a personal choice. Thus, it is unlikely that children will continue in a program if they do not understand the games or are unable to perform the exercises. Along with the primary objective of engaging youth in fun physical activities, professionals who work with children and adolescents are also responsible for class management, quality instruction, transition periods, and skill development. Needless to say, the development of successful youth fitness programs requires preparation, coordination, and understanding of the physical and psychosocial uniqueness of childhood and adolescence.

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See also Pediatric Obesity, Sports, and Exercise

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Glossary

acclimation The process of adjusting physiologically or psychologically to different environmental conditions, such as altitude or temperature

acetabular labrum A ring of fibrous cartilage that runs along the socket of the hip joint

acetabulum The socket of the hipbone in which the head of the femur rests, forming a ball-and-socket joint

achondroplasia The most common form of dwarfism, a genetic disorder that affects the development and maturation of bone from cartilage

acromioclavicular (AC) joint The joint located at the top of the shoulder between the acromion and the clavicle

actinic conjunctivitis An eye disease characterized by inflammation of the conjunctiva due to prolonged exposure to ultraviolet light

acute fracture Break of bone or cartilage in which the fracture line is sharp and the surrounding bone appears normal

acute injury An injury that occurs with a rapid onset after a single event

adhesion Fibrous band of scar tissue that forms between tissues not normally bound together, often resulting from injury

agonist A contracting muscle that is resisted by an antagonist muscle

air embolism Any obstruction of the circulatory system caused by the entry of air bubbles into the bloodstream, often through ruptured alveoli

all-around development The emphasis on the development of the three primary attributes of athleticism, flexibility, and musculoskeletal and cardiovascular capacities

allograft The surgical transplant of tissues or organs between different individuals of the same species

ALPSA (anterior labral periosteal sleeve avulsion) A lesion at the distal end of the shoulder associated with shoulder dislocation

alternative medicine Healing practices that fall outside the realm of conventional medical practice, such as homeopathy, acupuncture, naturopathy, or herbalism

alveoli Tiny air sacs within the lungs that facilitate the exchange of carbon dioxide and oxygen; the terminal points of the airways within the lungs

amenorrhea The absence or abnormal cessation of a menstrual period in a premenopausal female when menstruation should be present

anabolic-androgenic steroid A synthetic drug that is used to stimulate muscle and bone growth by mimicking the male hormone testosterone

anaerobic threshold The point during exercise when the body begins to work the muscles without the use of oxygen; the limit at which aerobic exercise can be maintained

aneurysm An abnormal blood-filled swelling of an artery or vein from weakness of the blood vessel wall

ankle inversion test A range-of-motion test performed on the ankle; positive tests reveal a potential tear of the calcaneofibular ligament of the ankle

annular ligament A strong band of fiber that surrounds the wrist or ankle joint

anomalous coronary arteries Congenital variation in the origin, pathway, termination, number, or structure of the coronary arteries; most anomalies are clinically silent and do not affect quality of life

anorexia athletica A condition in which people engage in excessive exercise to lose weight, typically associated with anorexia nervosa

anorexia nervosa A condition in which people intentionally starve themselves for fear of gaining weight, usually characterized by extremely low body weight and body image distortion

antagonist The counterpart of the contracting, or agonist, muscle responsible for the lengthening or stretching of the agonist

anterior apprehension test A clinical test for assessing the instability of a shoulder, in which apprehension with abduction and external rotation of the joint suggests anterior instability

anterior drawer test A measure of the stability and integrity of the anterior cruciate ligament of the knee

aortic stenosis A cardiovascular disease characterized by the abnormal narrowing of the aortic valve between the left ventricle and the aorta

Apley grind test A commonly applied diagnostic test in which the physician grips the hand of the patient and applies downward pressure, causing the hand to deviate toward the ulna

Apley scratch test A clinical test used to assess the range of motion of the shoulders by asking the patient to scratch his or her back

Apley test A clinical test used to assess knee or shoulder injuries

apophysis A natural swelling or outgrowth, or protuberance, on any part of a bone

apophysitis An inflammation of an apophysis

apprehension test A clinical test used to assess the location and severity of injuries, which is performed by manipulating a patient's joints and gauging his or her pain response

arachnoid mater The weblike protective covering of the brain and spinal cord; the middle of the three layers of meninges

arrhythmogenic right ventricular dysplasia A genetic disorder of the heart that is characterized by abnormal, arrhythmic ventricular contractions

arteriovenous malformation A congenital disorder characterized by an abnormal connection of veins and arteries, often resulting in internal bleeding and headaches

arthrofibrosis A condition most often associated with the knee, characterized by the growth of scar tissue resulting in limited joint mobility

arthroscopic portal Small incision through which arthroscopic surgery is performed

arthroscopy A minimally invasive surgery that allows the physician to examine the interior of a joint and diagnose and treat common knee, shoulder, and other joint problems

articular (hyaline) cartilage A tough, fibrous connective tissue that forms on the surface of bones within joints and aids in joint mobility

aseptic necrosis A condition in which the lack of blood supply to the bone may cause bone tissue death

ataxia The lack of motor coordination or the inability to coordinate skeletal muscle contractions

athlete's heart syndrome A medical condition in which the heart enlarges in response to the physiologic stresses of strenuous physical training; typically benign but difficult to distinguish from more serious cardiovascular illnesses

athlete's nodules A general term for relatively hard, discrete, roughly spherical, abnormal cutaneous masses occurring in individuals who engage in sports

athletic pseudonephritis The occurrence of protein and white and red blood cells in the urine in response to strenuous physical activity, often mimicking the problems associated with kidney disease but clearing up completely after 3 days of rest

atlantoaxial instability Increased flexibility of the ligaments between the atlas and the axis, the two bones at the top of the spinal column, with neurologic symptoms occurring when the spinal cord is affected

atlas (vertebra) The uppermost cervical vertebra of the spine

atopy An allergic reaction that becomes apparent almost immediately in response to a stimulus; genetically determined hypersensitivity to an allergen

ATP (adenosine triphosphate) A complex chemical compound derived from adenosine that is formed by the energy released from food and is used to perform cellular metabolic functions; energy molecule of a cell

auditory exostosis Benign bony growth located in the external auditory canal; frequently present in athletes who engage in water sports

autograft Tissue that is taken from one site and grafted onto another in the body of the same individual

avascular necrosis Death of the cells in a bone or joint due to depletion of blood supply

avulsion A painful separation of a muscle from its attachment to a bone

avulsion fracture Bone fracture that occurs when a tendon pulls off a piece of bone from a larger bone mass, usually as a result of a violent or forceful muscle contraction

axial compression test A test performed by pressing on the top of the patient's head with his or her neck in a neutral position; test is positive if the pain is aggravated

axial pain (syndrome) Pain referring to the central part of the body; back pain distinguished from the limbs

axis The second uppermost cervical vertebra, which provides a pivot for turning the head

axon A long extension of a neuron responsible for conducting a signal away from the cell body

balance The capacity to remain in a controlled position without falling or losing coordination

Bankart lesion A tear of the anterior glenoid labrum that is caused by violent movement of the arm

Basilar skull fracture Fracture that occurs at the base of the skull or the portion underneath the brain

belly press test A clinical test used to assess the function of one of the four muscles of the rotator cuff located within the shoulder, the subscapularis; performed with the patient in a standing position with his or her hand on the stomach, pushing as hard as possible

Bennett fracture A bone fracture of the first metacarpal between the thumb and wrist

bipartite Consists of two parts or divisions

Blount disease A growth disorder of the tibia in which the lower leg angles inward; characterized by a bow-shaped lower leg

bony Bankart lesion A fracture of the front lower portion of the glenoid; *see* Bankart lesion

bony edema A swelling of a bone that occurs following an injury

boutonniere deformity A deformity of the finger in which the joint nearest to the knuckle is bent inward due to misalignment of the tendons

bowlegs Legs that bend outward instead of angling inward; the opposite of knock-knees

boxer's fracture A fracture in the fourth or fifth metacarpal, which comprises the knuckles

brachial plexus An arrangement of nerves that conducts signals from the spine to the shoulder and allows for movement of the arm

bronchitis A respiratory disorder characterized by inflammation of the mucus membranes lining the bronchial tubes

bronchoconstriction Constriction of the bronchioles (airways in the lungs) due to the tightening of surrounding smooth muscle; can cause coughing, wheezing, and shortness of breath

bulge Swelling or outward protrusion

bulimia nervosa An eating disorder characterized by episodes of binge eating followed by behaviors designed to prevent weight gain, such as purging, fasting, or excessive exercise

bursa (*pl.,* bursae) A small, fluid-filled sac that provides a cushion between bones and tendons and/or muscles around a joint. Aids in reducing friction between bones and allows free movement

bursitis Painful inflammation of a bursa caused by pressure, repetitive stress from overuse, or infection

cam impingement An abnormal shape of the proximal femoral epiphysis that causes the femoral head to fit awkwardly within the socket, resulting in mild to severe pain

capsulorrhaphy arthropathy A disease afflicting the shoulder characterized by deterioration of the joint surface due to previous repairs of recurrent dislocations

cardiovascular drift A phenomenon that describes an increase in heart rate with prolonged exercise (greater than 10 minutes) despite the exercise continuing at the same intensity

catharsis In psychiatry, the process of release of repressed memories, ideas, or emotional tension

cauda equina syndrome A serious neurological condition characterized by a dull pain and numbness in the buttocks, genitals, and/or thigh with uncontrolled bladder and bowel function due to compression of the spinal nerves

central nervous system The part of the nervous system consisting of the brain and spinal cord; responsible for integrating environmental signals

cerebral edema An excess accumulation of fluid in the intracellular and extracellular spaces of the brain; a serious condition requiring emergency treatment

cerebrospinal fluid The fluid surrounding the brain and spinal cord that protects the spinal cord and provides nutrients

cervical spine The part of the vertebral column comprising the first seven vertebrae inferior to the skull

chair sign A clinical test to check for elbow stability and integrity, in which the patient is seated with elbows flexed at 90°, with forearms supinated and arms abducted, and then tries to rise from the chair pushing down only with the arms

chiropractic An alternative or complementary medical system that focuses on maintaining correct alignment of the musculoskeletal system; spinal manipulation is the most common treatment method, and many people visit chiropractors for treatment of low back pain

chondrolysis Disappearance of the cartilage on the joint surface of the femur (articular cartilage) as a result of disintegration or dissolution

chondromalacia A degeneration or softening of the articular cartilage

chondromalacia patella A softening of the cartilage on the articular surface of the patella that causes pain, particularly during flexion

chondroplasty The smoothing of torn cartilage on the joint surface

chronic exertional compartment syndrome An exercise-induced neuromuscular condition that causes swelling and pain in the arms and legs

closed fracture A fracture that does not pierce the skin

coarctation of the aorta A congenital disorder characterized by narrowing of the aorta, thereby decreasing blood flow to the body

coccyx The end of the spinal column; the base of the spine where the vertebrae are fused

co-contraction A type of contraction when both agonist and antagonist muscles fire at the same time

Colles fracture A fracture to the distal end of the radius bone located in the forearm

comminuted fracture A fracture involving extensive fragmentation of bone

commotio cordis Sudden heart failure due to a severe blow to the chest; most common in extreme contact sports

compartment A group of related muscles found in the same area of the body

compartment syndrome An acute medical issue characterized by the overuse of the same muscle or muscle group and decreased blood flow in a confined anatomical space

complementary medicine A diverse set of systems of holistic medicine based on philosophies other than those used in conventional Western medicine; often called *preventive medicine*

compound fracture The former term for a broken bone that has gone through the skin; now called *open fracture*

concentric movement The part of the movement where the agonist muscle contracts, for example, the lifting motion of an exercise

concussion An injury to the brain caused by a violent blow or rapid shaking; a mild concussion may involve no loss of consciousness; severe concussion may cause prolonged unconsciousness. An athlete who has had a concussion should return to play only with a physician's approval

conditioning Development of physical fitness through adaptation of the body and its various systems to a program of exercise

conduction The act of transmitting heat, sound, or nervous impulses from one area of the body to another

condyle A rounded epiphysis of a bone usually encased in the articular cartilage

contralateral Of or relating to the opposite side

contusion A blunt force injury that does not break the skin but causes underlying tissue damage, with bleeding under the skin (bruising)

convection The transfer of heat via gas or liquid

coordination The ability to conduct more than one set of muscle movements in unison

coracoid The bony prominence of the scapula

costochondritis An inflammation at the point where the ribs fuse with the sternum

crepitus A grinding noise or sensation within a joint or the lungs

cruciate Cross-shaped

crutch palsy Compressive injury to the nerve complex (the brachial plexus) located in the underarm

cyanosis A medical condition characterized by a bluish discoloration of the skin or mucous membranes; a symptom that indicates a dangerously low level of oxygen in the discolored area

de Quervain disease *See* de Quervain tenosynovitis

de Quervain tenosynovitis A painful inflammation of the tunnel that surrounds the two tendons that control the movement of the thumb

debridement Surgical removal of dead, damaged, or infected tissue and foreign matter from a wound or burn

deep vein thrombophlebitis The formation of a blood clot within a vein, typically located in the leg; causes the extremity to become swollen, painful, red, and/or warm

dehydration An excessive deficiency of body water

dens A superior projection of the vertebral body that goes up into the anterior ring of the atlas

depressed skull fracture A skull fracture in which fragmented bones press into brain tissue and cause neurological trauma

dermatophyte A parasitic fungus that infects the skin

dermis The deep vascular layer of the skin located beneath the epidermis

diabetes mellitus A condition characterized by hyperglycemia, resulting from the inability to appropriately control blood sugar and regulate insulin levels

diaphragm A muscular partition between the thoracic and abdominal cavities that regulates breathing

diaphragmatic breathing The act of breathing deep within the lungs by focusing on lowering the diaphragm rather than expanding the chest

diaphysis The main shaft of a long bone

diastatic skull fracture Fracture that occurs along the growth plates or sutures of the skull

disability A physical or mental impairment that prevents a person from performing one or more major life activities

disk herniation A condition of the vertebral column in which a tear in the outer, fibrous ring (nucleus pulposus) of an intervertebral disk allows the soft, central portion (anulus fibrosus) to bulge out, commonly known as a *slipped disk*

disk-osteophyte complex A medical condition where the soft tissue of the intervertebral disk extrudes beyond its normal parameters

displaced Pertaining to the removal from the normal position, location, or place

distraction test An orthopedic test performed on the knee; positive tests indicate a ligamentous injury of the knee

diuretic Any substance that increases the amount of urine production by the kidneys and reduces the amount of water in the blood, thereby decreasing the blood volume

dorsal Pertaining to the back surface of a body part, such as the backside (knuckle side) of the wrist and hand

dorsiflexion Backward flexion or bending toward the dorsal side; flexing the ankle and pointing the toes upward

drawer test An orthopedic test that is used to detect torn cruciate ligaments in the knee

dura *See* dura mater

dura mater The outermost layer of the meninges, the membranes surrounding the brain and spinal cord

dysesthesia A condition characterized by an unpleasant, abnormal sensation such as burning, caused by lesions of the nervous system

eccentric contraction A condition that occurs when the force generated by the muscle cannot overcome the resistance placed on the muscle; also, a lengthening contraction of the muscle

eccentric movement A movement in which the agonist muscle elongates

ecchymosis The escape of blood within subcutaneous tissue that results in discoloration or bruising

echocardiogram A sonar imaging scan used to study the structure and motions of the heart

edema A swelling of tissue due to the accumulation of excess fluid

effusion The discharge or outpouring of a fluid into a body cavity

electrocardiogram A medical record that is used to measure the electrical rhythms of the heart

endogenous Produced, occurring, or caused by factors within the body of an object or organism

endotenon A thin retinacular structure investing each tendon fiber

endurance The ability to withstand stress and hardship or sustain an activity over time; a measure of stamina

epicondyle A protrusion of a bone above the condyle that provides the surface area to which ligaments and tendons can attach

epidermis The outermost layer of the skin surface of vertebrates, which is on top of the dermis

epidural space The space between the dura mater and the lining of the spinal canal

epiphysis The rounded end of a long bone

epitenon A component that surrounds the tendon and contains the vascular, lymphatic, and nerve supply and is in turn surrounded superficially by the paratenon

erythema An abnormal red discoloration of the skin due to the dilation of cutaneous blood vessels

euhydration A normal state of body water content

evaporative heat loss The loss of body heat due to the evaporation of sweat from the body

excision Surgical removal of a portion or all of an organ or other structure

exercise-associated hyponatremia Dangerously low levels of sodium within the blood due to excessive exercise

exercise-induced hematuria The presence of blood within the urine due to excessive exercise

exogenous Produced, occurring, or caused by factors outside the body of an object or organism

extra-axial hemorrhage Blood loss within the intracranial space; increases pressure, causing headaches

extreme-risk injury Injury needing immediate medical attention

extrusion A bulge or protuberance, pushing out

facet joints Small joints located between adjacent vertebrae

fascia A continuous sheet of connective tissue that separates and bonds together muscles and other organs

fasciotomy A surgical procedure in which fascia is removed from the body to relieve tension and pressure

female athlete triad A medical condition seen in some female athletes, characterized by disordered eating, amenorrhea, and osteoporosis

FEV_1 (forced expiratory volume in 1 second) The volume of air an athlete can expel in the first second of a forced expiration; the most important parameter examined in determining airway obstruction

first-degree strain A minor strain characterized by only a few muscle fiber tears

flail chest A severe medical condition characterized by fragmentation of the ribs due to stress

flexibility The ability of a muscle or extremity to relax and yield to stretch forces

focal fibrocartilage dysplasia An uncommon, normally harmless bone lesion that causes deformity of the long bones in youth

fontanelle The gaps located between the bones of the cranium in an infant or fetus

foramen (*pl.*, foramina) Any opening or orifice within the body

Freiberg disease An osteochondrosis affecting the metatarsals (long bones of the foot)

Freiberg sign The reproduction of pain caused by passive internal rotation of the hip with the leg in an extended position

fulcrum test By placing the left hand under the glenohumeral joint to act as a fulcrum, the apprehension test becomes a fulcrum test

functional limitation Any health problem that prevents an individual from completing a task

ganglion cyst A small, abnormal, fluid-filled sac (usually less than 2 centimeters) that develops near a joint capsule or tendon sheath

gastrocnemius soleus (calf muscle) strain A strain or tear, with the sensation of a pop being felt, due to the simultaneous stretching and active contraction of the muscle

genu valgum A medical condition characterized by an inward curvature of the legs so that the knees touch when a person is standing straight; commonly known as *knock-knees*

genu varum A medical condition characterized by an outward curvature of the legs; commonly called *bowlegs*

GLAD lesion (glenolabral articular disruption) Lesion characterized by a labral tear associated with an injury to the glenoid articular cartilage

glenohumeral joint The shoulder joint that functions as a ball-and-socket joint; composed of the glenoid socket and the humeral head

glenohumeral ligaments Three bands of connective tissue that strengthen the glenohumeral joint

glenoid Any shallow depression of a bone resembling a pit or socket

glenoid labrum A rim of articular cartilage that surrounds the margin of the glenoid cavity in the shoulder blade

glial cell Nonneuronal cell that provides nutrients and removes waste from other neural cells

glycogenolysis The process by which glycogen is broken down in the liver into individual molecules of glucose

gout A form of arthritis caused by a buildup of uric acid in the joints

gradual progressive throwing A shoulder rehabilitation technique in which throwing motions help stabilize the shoulder

gray matter A large component of the central nervous system comprising glial cells, neuronal cell bodies, dendrites, axons, and capillaries

grind test A clinical test used to determine the integrity and problems associated with the meniscus of the knee

Hawkins-Kennedy test A test that attempts to cause external compression of the rotator cuff and consequently re-create the patient's pain

hemarthrosis Bleeding into joint spaces

hematocrit The volume percentage of red blood cells in a blood sample

hematoma Swelling formed by excess accumulation of blood

hematopoiesis The production of blood cells

hemorrhage A copious discharge of blood from the blood vessels

hemothorax Accumulation of blood located within the pleural cavity, or the area surrounding the lungs

hepatitis Inflammation of the liver caused by certain viruses or other factors such as alcohol abuse or medications

hepatomegaly Abnormal enlargement of the liver

heterotopic bone formation/ossification The formation of bone in abnormal locations, such as in soft tissue or muscle

Hill-Sachs lesion A depression in the head of the humeral epiphysis due to a forceful impact against the glenoid rim

hip dysplasia An abnormal formation and deterioration of the hip socket that is characterized by excessive pain and arthritis

hip impingement A condition that is characterized by excessive friction within the ball-and-socket hip joint

hip quadrant test A clinical test that indicates arthritis, avascular necrosis, and/or an osteochondral defect within the hip

Homans sign A sign of deep vein thrombosis; is positive when pain is located within the calf muscles

hop test A clinical test used to measure the horizontal and vertical power of the legs by performing three consecutive jumps

hydrogenation A form of chemical reduction, a chemical reaction between molecular hydrogen (H_2) and another compound or element, usually in the presence of a catalyst; commonly employed to reduce or saturate organic compounds

hyperpronation The extreme inward rotation of the foot during gait

hyperalgesia An increased response to pain caused by damage to the peripheral nerves

hyperesthesia A state of abnormal increase in sensitivity to sensory stimuli

hyperlipidemia An excess quantity of lipids in the blood

hypertrophic cardiomyopathy A condition where the heart muscle becomes abnormally enlarged, limiting the amount of blood that can enter the heart and thereby reducing pumping ability

hyphema A collection of blood in the anterior chamber of the eye often caused by trauma; causes blurry vision, pain, and tearing

hypodermis The lowermost subcutaneous level of the three skin layers

hypohydration *See* dehydration

hypothalamus The part of the brain responsible for the control of endocrine glands and the autonomic nervous system

hypoxia Decreased availability of oxygen to body tissues

iatrogenic Describing inadvertent harmful consequences or complications resulting from medical treatment

idiopathic A disease of an unknown origin

iliotibial band A band of fascia that spans from the iliac crest of the pelvis region to the knee joint; can become inflamed due to excessive running

impingement Striking or excessive pressure on a tissue, often from encroachment by adjacent structures

infective endocarditis An inflammation of the membrane that lines the cavities of the heart and forms part of the heart valves, generally caused by an infection

influenza An acute, highly contagious viral disease; also referred to as the *flu*

inguinal hernia A protrusion of the intestines through the inguinal canal where the flesh of the abdomen meets the thigh

injury, catastrophic An extremely serious injury that may result in disability and loss of bodily functions, with full recovery doubtful

injury, nonfatal A broad range of types of injury from acute to catastrophic with no life-threatening issues

injury, serious An injury in which mortality is probable

integrative medicine A combination of alternative and conventional medicine to provide a more comprehensive healing plan for the patient

intersection syndrome Inflammation of the crossover area where the musculotendinous junctions of the first dorsal compartment meet with the tendons of the second dorsal wrist compartments

interval training An exercise strategy in which an athlete raises his or her exercise intensity above the anaerobic threshold for a short period of time and then dips back below the threshold and keeps exercising

intervertebral disk A fibrocartilaginous disk that provides cushion and support between two adjacent vertebrae

intervertebral foramen An opening between vertebrae that transmits nerves from the spine throughout the body

intraarticular dilation An expansion within the joint

intra-axial hemorrhage A hemorrhage that takes place within the central part of the body

iontophoresis Therapy that uses small electric currents to deliver medicine into tissues of the body

ipsilateral Positioned on or affecting the same side

irrigation Cleansing injured tissue by rinsing with sterile saline, with or without antibiotics in the solution

ischemic necrosis A condition in which the lack of blood supply to the bone may cause bone tissue death

isometric contraction A contraction that generates muscle force but in which no joint movement occurs, such as holding a squat for 10 seconds

isotonic contraction A contraction that occurs when the muscle contracts and joint movement occurs

jerk test A clinical test used to determine the integrity of the knee joint (possible torn meniscus), also called Hughston's jerk test, to distinguish from the simple knee-jerk test of neurological reflex by tapping the patellar tendon.

Jobe's empty can test A clinical test used to determine the integrity of the supraspinatus tendon

joint aspiration The removal of fluid from within a joint

joint effusion The escape of intraarticular fluid

joint integrity A measure of the stability and durability of a joint

joint of Luschka Small synovial joints between adjacent lower-cervical vertebral bodies—a frequent site of arthritis formation

Jones fracture A fracture of the fifth metatarsal of the foot

knock-knees A condition in which the legs curve inward at the knees; *see* genu valgum

kyphosis An abnormal backward curve in the spinal column

labrum A thickened portion of connective tissue that surrounds the sockets of the shoulder and hip joints

Lachman test A test that is used for examining the integrity of the anterior cruciate ligament of the knee

lactate threshold The point at which lactic acid buildup in the muscles begins to impair performance

lamina (*pl.*, laminae) A broad plate which extends from the pedicle to the median line of the vertebra, two laminae fusing to complete the roof of the vertebral arch

laminectomy Surgical removal of any part of the lamina

lateral epicondylitis A painful inflammation of the tendon that wraps around the elbow; also called *tennis elbow*

lateral pivot-shift test A clinical test used to evaluate the anterolateral structures of the knee

lift-off test A clinical test used to check the stability of the shoulder

ligaments Fibrous connective tissues responsible for connecting bones, cartilage, and other structures

linear fracture A fracture that runs parallel to the axis of the bone

load and shift test An orthopedic test used to check for the stability and integrity of the shoulder

loose body A free-floating piece of bone or cartilage that has broken away and is moving around a joint

lordosis An inward forward curve of the lower spine

lucid interval A temporary improvement in a patient's condition following a traumatic brain injury, after which the patient's condition deteriorates

Ludloff sign A test checking the ability to flex the thigh while sitting down; is positive if patients fail to perform the test, and negative if performed effectively

lumbar The portion of the spinal column between the thorax and the pelvis, commonly called the lower back

luteal phase The second half of the menstrual cycle lasting from ovulation to menstruation

malleolar bursitis Swelling and pain over the ankle bone caused by irritation of the bursa, a fluid-filled sac that aids in reducing friction between moving bones

McMurray test A test used to determine whether a meniscal tear is present in the knee by bending the lower leg, straightening it out, and rotating it; is positive if pain is found around the area of the meniscus

medial and lateral patellar glide test A test used to determine the stability of the lateral retinaculum in the knee and the medial aspect of the knee

medial epicondylitis An overuse injury, commonly known as *golfer's elbow,* that causes pain in the inside of the elbow

medial tibial stress syndrome An overuse injury, commonly known as *shin splints,* causing irritation in the shinbone, which is located in the front of the lower leg

mediastinum The central cavity surrounded by the lungs, containing the heart, proximal aorta, and vena cava and lined by a protective tissue, the pericardium

meninges Protective coverings of the brain and spinal cord, consisting of three layers from outermost to innermost—namely, the dura mater, arachnoid, and pia mater

meniscal cartilage The cushioning tissue of the knee between the femur and the tibia

meniscus A structure consisting of both the lateral and the medial cartilage of the knee, acting as a pad between the joints of the femur and the tibia and providing a smooth surface for the joints to glide on

menorrhagia Excessive menstruation that lasts for more than 7 days

metabolic ketoacidosis A condition that usually affects patients with diabetes when the body has very low levels of insulin and starts to break down body fat, leading to the formation of a high concentration of ketone bodies, and thus causing the blood to become too acidic

metaphysics The study of reality in relation to such questions that may not be answered scientifically; also, the study of subjects relating to mind and matter

metatarsalgia An overuse injury that causes pain in the middle region of the forefoot

microfracture A surgical technique in which tiny holes are made in the exposed bone in an area of the joint where the full thickness of the cartilage has been completely damaged

microtrauma The term given to microscopic injuries such as microtears in muscles, tendons, and tissues

milk test An orthopedic measure to test elbow instability

Monteggia fracture A break in the ulna bone of the forearm, along with dislocation of the radial head

Morton neuroma Irritation, pain, and swelling of the nerve located between the third and fourth toes of the foot

moving valgus stress test A test used to determine whether the medial collateral ligament (MCL) of the elbow is torn

MR (magnetic resonance) arthrogram A test used to examine the joints in the body, such as the knee or shoulder, in which a contrast-enhancing dye is injected to facilitate viewing by magnetic resonance imaging

muscle hypertrophy The increased cross-sectional size of the muscle fibers

muscle strength The ability of the muscle to create force against physical objects

muscular endurance The ability of a muscle to perform and maintain repeated muscle contractions over long periods of time

myocarditis An inflammation of the heart muscle (myocardium)

myocardium Cardiac muscles that make up the bulk of the heart wall

myofascial release The adding of pressure with the thumb over the muscle spasm to decrease the contraction

myositis ossificans The formation of bone within muscle tissue; occurs after the tissues surrounding the muscles are damaged in a traumatic injury

Neer test A test that attempts to cause external compression of the rotator cuff and consequently recreate the patient's pain

nerve impingement (or "pinching" of the nerve) Refers to pain in or impaired function of a nerve that is under pressure

nerve root A part of a collection of nerve fibers that branch off from the spinal cord. Dorsal roots are composed of sensory fibers that bring information into the spinal cord. Ventral roots are composed of motor neurons that carry commands from the spinal cord to the muscles and internal organs

nerve tracts A collection of nerve fibers located in the central nervous system (CNS)

neurons Nerve cells; the conducting cells of the nervous system that receive and transmit information through chemical and electrical signals

Noble compression test A test used to check for iliotibial band syndrome

nondisplaced A type of fracture in which the bone maintains its normal alignment after breaking

nonpurging-type bulimia nervosa An eating disorder involving excessive eating along with attempts to compensate afterward through diet pills, fasting, or excessive exercise

nonunion A fractured bone that failed to heal properly

nuchal ridge A thick crest located on the back of the neck and base of the skull (occipital bone)

nucleus pulposus A gelatinous substance found in the center of intervertebral disks of the spinal column; aids in shock absorption

Ober test A test used to evaluate the shortening of the iliotibial tract muscle

O'Brien test A test used to evaluate acromioclavicular joint injury in the shoulder

OCD *See* osteochondritis dissecans

occipitocervical injuries An injury of the cervical spine in which the cranium dislocates from the neck, a severe injury that can be fatal if not treated immediately

odontoid process A toothlike structure found in the second vertebra of the neck

open fracture A fracture in which the bone penetrates through the skin, also called a compound fracture

orthorexia nervosa An eating disorder characterized by an excessive concern with eating healthy foods (not officially recognized as a medical diagnosis)

orthosis A support device used to brace or correct the function of specific limbs—for example, arch supports that are used to correct foot function

os acromiale Pain in the shoulder due to the failed fusion of the bone at the front of the shoulder roof known as the acromion

os odontoideum A separation of the top of the dens from the C2 vertebral body

ossicle The smallest bones in the body, of which three are located in the middle ear

osteoarthritis A form of arthritis; a degenerative disease that affects joints and also leads to the gradual breakdown of cartilage and the formation of "bone spurs" on joints

osteoblasts Cells in the body that are responsible for bone formation

osteochondral injury An injury that affects the articular cartilage and the bone underneath

osteochondritis Inflammation of bone and cartilage

osteochondritis dissecans (OCD) An injury in which fragments of cartilage and bone are separated from the end of the bone and are loose in the joint space

osteochondrosis The necrosis or breakdown of growth centers in the pediatric or skeletally immature patient followed by regeneration or healing

osteoclast A body cell that not only breaks down bone tissue but also absorbs it back into the body

osteolysis The active resorption of bone matrix by osteoclasts as part of an ongoing disease process

osteonecrosis A condition in which the lack of blood supply to the bone may cause bone tissue death

osteopenia A condition in which the level of bone mineral density is below normal levels, but not as severe as in osteoporosis

osteophyte An abnormal growth of bone in damaged joint areas, more commonly known as a *bone spur;* commonly seen in osteoarthritis due to the nature of degenerative joints

osteoporosis A disease that causes bones to lose density, strength, and tissue over a period of time, leaving bones fragile and more susceptible to injuries such as fractures

osteotomy A surgical procedure that involves cutting the bone to promote proper alignment and healing in the affected joint area; can be used for arthritis treatment and to fix bones that may have grown incorrectly

otalgia Ear pain, of which there are two types: (1) pain originating from the outside of the ear, or *referred otalgia*, and (2) pain that originates from within the ear, or *primary otalgia*

otorrhea A discharge of fluid from the ear canal

Ottawa ankle rules A set of guidelines established to help physicians determine whether X-rays are needed to diagnose possible fractures in the foot or ankle

Ottawa knee rules A set of guidelines established to help physicians determine whether X-rays are needed to diagnose knee injuries

outer annulus The outermost layer of fibrocartilage in an intervertebral disk, tears or ruptures of which may permit extrusion of the nucleus pulposus into the surrounding tissue

overreaching A condition in which an athlete trains excessively, causing stress, fatigue, and sometimes poor athletic performance

Pace sign A test used to determine whether a patient has piriformis syndrome, a compression of the sciatic nerve by the piriformis muscle of the thigh

paraplegia Partial or complete paralysis of the lower extremities caused by a spinal cord defect or traumatic injury

paratenon The external covering of the entire tendon

paratenonitis Inflammation of the paratenon, the outermost layer of the tendon

paresthesias The occurrence of abnormal nerve sensations such as tingling, burning, itching, and "pins and needles," sometimes caused by nerve damage

parietal pleura A specialized skinlike surface that lines the thoracic cavity

patellar tendinosis Inflammation or long-term damage to the tendon that connects the bottom of the kneecap to the top of the shinbone

patellar tendon The attachment of the quadriceps muscle to the tibia

patellar tilt test A test used to assess the tightness of the lateral side of the knee and also pain around the kneecap (patella)

Pavlik harness A soft brace used for babies less than 6 months old with thighbone fractures

periodization The process of splitting up time into blocks; in sports medicine, the splitting up of a training regimen into phases

periosteum A membrane/tissue covering all bones

peripheral nervous system Composed of the nerves outside the brain and spinal cord, which also connect the central nervous system to the sensory organs, limbs, and muscles

pertussis A contagious bacterial disease that causes violent coughing, commonly known as whooping cough

pes planus A condition in which the arch of the foot collapses and touches the ground, commonly called *flat feet*

petechiae Round red spots that are visible on the skin due to bleeding under the skin

phalanges (*sing.*, phalanx) The bones of the fingers and toes

pharmacokinetics The study of what happens to a drug after it is taken into the body, that is, how it is metabolized

phonophoresis A technique using ultrasound to help the body absorb therapeutic drugs through the skin

physiatrist A physician who specializes in physical and rehabilitation medicine

physis The growth plates at the ends of long bones

pia mater The innermost layer of the meninges, the membranes surrounding the brain and spinal cord

pincer impingement A form of hip abnormality in which the front edge of the hip socket sticks out too far

piriformis sign A test used to determine whether the pain originating in the gluteus maximus causing referred pain down the leg is due to piriformis syndrome

pivot-shift test A test used to determine the stability of the anterior cruciate ligament (ACL) in the knee

plantar fascia A series of connective tissues that start from the heel and support the arch in the foot

plantarflexion Bending of the foot in a downward direction

pleura A membrane that surrounds the lungs and also covers the diaphragm and lines the inner chest wall, forming a potential space for lung expansion

pleural cavity The body cavity that surrounds the lungs

plica syndrome An inflammation of the plica (*see* plicae) found in the knee

plicae Bands of synovial tissue located in the lining of a joint

plication A surgical procedure used to tighten tissues by folding them into tucks and suturing them

pneumomediastinum A pathological condition consequent to trauma to the chest in which air leaks from the injured lungs into the middle of the chest (mediastinum)

pneumonia An inflammation of the lungs caused by infection

pneumothorax A serious condition that occurs following the collapse of a lung, in which air collects in the pleural space surrounding the lungs and makes breathing difficult

popliteal Refers to the structures in the back of the knee, such as veins, nerves, arteries, and so on

positive J sign A test that shows the patella tracking laterally as the knee changes from flexion to extension

posterior drawer test A test to evaluate the posterior cruciate ligament (PCL) in the knee, especially for tears and ruptures

posterior Lachman test A test used to diagnose a torn anterior cruciate ligament (ACL)

posterior sag test A test used to determine instability in the posterior cruciate ligament

posture The position in which the body is held upright against gravity while standing or sitting down

power A force that is exerted over a period of time

progressive muscle relaxation A set of skills whereby the athlete is trained to control the tension of his or her muscles by alternatively consciously flexing them, holding the tension, and then slowly releasing them

progressive overload The increased stress placed on the body during exercise

prolotherapy A form of therapy that involves injection of a substance into the body to strengthen weakened tissues and also alleviate pain

proprioception The ability to sense the position and movement of muscles

protrusion An extension beyond the usual limits

pseudocyst An abnormal sac that resembles a true a cyst but lacks membranous lining

pterygium An abnormal growth that begins on the white of the eye and invades the cornea, the clear tissue covering the iris and the pupil, which may result from overexposure to sunlight and can be surgically removed. May also refer to a winglike triangular membrane abnormally occurring in the neck, eyes, knees, elbows, ankles, or digits

pudendal nerve compression syndrome Pain in the pelvic area due to compression activities such as cycling

pudendal nerve entrapment syndrome Chronic pain in the pelvic area due to stretching, inflammation, or compression of the pudendal nerve

pulmonary contusion Bruising of the lungs that causes pain and difficulty in breathing

pulmonary edema Excess fluid buildup in the lungs; can be caused by circulatory problems such as congestive heart failure

pulse oximetry A method in which the oxygen saturation of the hemoglobin is monitored

purging-type bulimia nervosa A type of disorder in which the bulimia patient uses vomiting, laxatives, diuretics, or enemas to rid the body of consumed calories

purpura Bleeding under the skin characterized by purple or red discoloration spots

push-up sign A test for posterolateral instability in the elbow

pyrogen A substance that causes a rise in body temperature and subsequent fever; released by certain bacterial infections

quadriceps tendon The tendon above the patella (kneecap)

radiation heat loss The loss of heat from the body, most significant between sunset and sunrise, due to infrared emission

radicular pain Muscle weakness, tingling, numbing, and pain due to the compression of a spinal nerve root

radicular symptom Pain manifested in the legs or arms due to a compressed spinal nerve root

radiculopathy The inflammation of spinal nerve roots

reduction The technique of returning a fractured bone to its proper alignment

release test A test in which a force that decreases the patient's pain is removed, causing the pain to return

relocation test A test used to determine whether anterior instability is present within the shoulder

Renee creak test A test used to diagnose pain and tightness in the iliotibial band; is positive if pain is present when standing on the affected leg with knee flexion at 30°

retromalleolar groove A concavity located in the fibula, which when abnormally shaped can lead to tearing of the peroneus brevis (PB) tendon

reversibility Reduction or complete loss of fitness as the result of not training

rheumatoid arthritis An autoimmune disorder that causes chronic inflammation in the joints and can also affect other organs in the body

rhinitis An inflammation of the mucous membrane inside the nose, commonly known as a stuffy nose, that is associated with the common cold and allergies

rhinorrhea Fluid nasal discharge; "runny nose." Following head injury, may indicate leakage of cerebrospinal fluid, a serious condition requiring prompt medical attention

ribs, false Five ribs, located inferiorly to the true ribs, called "false" because not directly connected to the sternum

ribs, floating The lowest two sets of ribs attached to the vertebrae in the lower back

ribs, true The uppermost seven pairs of ribs, attached to the sternum

rickets A disorder that leads to the weakening and softening of bones in children; caused by lack of vitamin D and, in some cases, lack of adequate calcium intake

righting reflexes A neuromuscular response that enables the body to regain its normal position when it has been displaced

rotator cuff A structure composed of four muscles that stabilize the shoulder joint and allow shoulder movement, namely the supraspinatus, infraspinatus, teres minor, and subscapularis

sacrum The triangular bone located in the base of the spine, composed of five fused sacral vertebrae forming the rear of the pelvis

sarcopenia The degenerative loss of muscle mass and strength due to aging

second-degree strain An injury in which the muscle is overstretched, causing inflammation and pain; involves most of the muscle fibers tearing and difficulty performing certain movements

second impact syndrome A condition involving a second concussion before the first has properly healed; a serious, often fatal injury in which the brain rapidly swells up, causing an increase in the intracranial pressure

secretory phase The second half of the menstrual cycle

septal hematoma Bleeding within the nasal septum

sequestration An abnormal separation of a part from a whole, such as a portion of a bone by a pathological process or a portion of the circulating blood into the surrounding soft tissue from a broken blood vessel

Sever disease Pain in the heel due to the inflammation of the growth plate (calcaneus) located in the back of the foot

shear injury An axonal injury to the brain due to accelerated rotational forces

shoulder capsule A structure that provides extra stability to the shoulder joint

SLAP lesion (superior labrum anterior-posterior) An injury to the glenoid labrum, located in the shoulder

slipped disk A condition of the vertebral column in which a tear in the outer, fibrous ring (nucleus pulposus) of an intervertebral disk allows the soft, central portion (anulus fibrosus) to bulge out. *See* disk herniation

slump test A physical examination to evaluate the sciatic nerve in cases of pain in the spinal and lower extremities

Smith fracture An injury to the distal radius (forearm bone)

spasm An involuntary contraction of a muscle

specificity A measure of a test's ability to rule out a disease

Speed test A test to evaluate whether pain is present in the bicipital groove of the shoulder

spica A body casting to treat fractures

spinal stenosis A narrowing of the space enclosed by the spinal column, causing pressure on the spinal cord

spirometry A test used to measure the breathing capacity of the lungs

spondylolisthesis Forward displacement of a vertebra over a lower segment due to a congenital defect or fracture in the pars interarticularis

spondylolysis The breaking down of a vertebra, usually leading to small stress fractures from an overuse injury

spondylolytic A term used to describe a patient with a degenerative disorder of the pars interarticularis, a structure found in the vertebrae

spondylosis A degenerative disorder that affects the intervertebral disks in the spine, often referred to as spinal osteoarthritis

sports concussion A head injury caused by either mild or severe impact during sports activity that causes the brain to shake violently within the cranium

sports hernia A condition that occurs when muscles and tendon in the lower abdomen become weakened, usually causing chronic groin pain in athletes; not a true hernia

Spurling test A test for pain in the neck originating from the spinal nerve roots

Stener lesion A condition that occurs when the ulnar collateral ligament (UCL) tears and the surrounding tissue of the overlying thumb tendon gets lodged between the torn UCL fibers

stenosis A condition in which the blood vessels and tubular organs become narrowed and constricted

strain The stretching or partial tearing of the muscle, resulting in inflammation and pain

strength The ability of a muscle to generate and resist physical force

stress fracture A small crack in a bone, usually caused by overuse

stress fracture test A bone scan used to evaluate the injured area on the bone

stretch reflex A muscle contraction in response to stretching within the muscle; also known as a myotatic reflex

stroke volume The amount of blood that is pumped out of a ventricle in the heart during a contraction

structural tolerance The ability to withstand weeks or months of high-volume training without the incidence of injury, illness, or fatigue that may lead to overtraining

Stryker notch view An X-ray view used to evaluate for Hills-Sachs lesion after a dislocation

subacromial impingement Pain in the shoulder caused by friction between the rotator cuff and acromion

subarachnoid space The meningeal space located between the arachnoid and the pia mater

subchondral bone A bone layer that underlies the articular cartilage

subcutaneous emphysema A pathological condition that occurs when air is trapped beneath the tissues in the skin of the chest, neck, and face

subdural space The space between the dura mater, the outermost meningeal layer, and the underlying arachnoid mater, caused by an injury or a pathologic process such as a subdural hematoma

subluxation A condition that occurs when the patella, commonly called the kneecap, becomes partially dislodged from its normal position

subtalar neutral position The normal position of the foot when one walks

sulcus sign A test to evaluate the presence of inferior instability within the glenohumeral joint

superior retinaculum The ligament binding the extensor tendons closest to the ankle joint

surfer's ear A condition that occurs when the ear canal becomes blocked due to abnormal bone growths, called exostoses, caused by prolonged exposure to cold water and wind

surfer's myelopathy A nontraumatic spinal cord injury in which blood flow to the spine is interrupted when the back is hyperextended, sometimes causing partial or complete paraplegia

swan-neck deformity A hand deformity in which the distal joint of the finger is pointed inward and the proximal joint outward

synchondrosis A cartilaginous joint that joins bone to bone, such as the sternocostal joints where the first ribs join the sternum

syncope A temporary loss of consciousness, commonly known as fainting

synostosis A condition in which two separate bones fuse together as one

synovial cyst A cyst that is filled with synovial or joint fluid to produce its characteristic bulge

synovial fluid The lubricant that serves to reduce friction of the articular cartilage within the joint capsule

synovial tendon sheath A membrane consisting of an outer fibrotic sheath and an inner synovial sheath, which may be found in areas subject to increased mechanical stress where efficient lubrication is required

synovitis An inflammation of the synovium, the tissue that lines the joints

synovium A soft tissue that lines the joints and produces synovial fluid

syringomyelia A disorder characterized by the formation of a cyst in the spinal cord

tachycardia A heart rate faster than normal

tarsal coalition A condition in which two bones in the back of the foot (tarsal bones) are fused

tendinitis The inflammation of the tendon; rarely occurs without the presence of underlying degenerative tendon change

tendinopathy Tendon injuries such as tiny tears, pain, and inflammation

tendinosis A noninflammatory repetitive injury to the tendon resulting in microtears that do not heal properly

tendon A band of fibrous connective tissues that connect a muscle to a bone

tenodesis stabilization Procedures that are indicated for patients with lateral ankle instability with failed anatomic repair; consists of a suture of the end of a tendon to a bone

tenosynovitis An inflammation of a tendon and its sheath

tenotomy A surgical procedure that involves cutting or releasing a tendon

tension pneumothorax A condition that forms a one-way valve, allowing air to enter the pleural space but not to escape; the buildup of air within the pleural space producing pressure on the lungs, thus making breathing difficult

tetraplegia A traumatic spinal injury that causes complete paralysis of all limbs

therapeutic exercise A therapy with goals such as improving musculoskeletal function, recovering from injuries, and providing relaxation

thermoregulation Control of body temperature

third-degree strain The most severe type of strain, which occurs when a muscle has been completely ruptured due to an injury

Thomas test A test used to evaluate whether a patient can extend the hips

Thompson test A test used to evaluate for an Achilles tendon rupture

thoracic kyphosis An abnormal forward curvature of the upper back region

thoracic spine The middle region of the spine, consisting of 12 vertebrae

tibia vara A growth disorder of the upper shinbone, causing a bowlegged appearance

tinea capitis A contagious infection of the scalp caused by a fungus, commonly called ringworm

tinea corporis A contagious fungal infection affecting the skin, commonly known as ringworm

tinea cruris A fungal infection affecting the groin area, commonly called jock itch

tinea pedis A fungal infection of the foot, commonly known as athlete's foot

Tinel test One of two tests used to diagnose the presence of carpal tunnel syndrome

tophi The buildup of uric acid in joints, bones, and cartilage

torticollis A pathological condition involving uncontrolled spasms of the neck muscles so that the neck remains in a twisted position with the head tilted and turned to one side

toss The act of disengaging a member of a cheerleading team from either a pyramid or a base arrangement

traction apophysitis An inflammation of an unfused apophysis caused by excessive pull of an attached tendon

training load The product of all three fundamental components of training: frequency, duration, and intensity

trans fat An unsaturated fat that is made into a solid by adding hydrogenated oils during manufacturing

Trendelenburg test A test to evaluate hip function, specifically of the gluteus medius muscle, in which the patient is asked to stand on one leg

triangular fibrocartilage complex A structure found in the wrist that is made up of several different structures, the primary components are being the dorsal and palmar volar ligaments

trochanter Two bony projections located near the end of the thighbone

trochlear groove The concave surface in the knee joint where the patella makes contact with the femur

tuberosity A protuberance on a bone, especially where a muscle or ligament is attached

turf toe Pain at the base of the great toe caused by jamming the foot

uncinate process Any hooklike process, such as that keeping a vertebra from sliding backward off the vertebra below it

uric acid A heterocyclic compound of carbon, nitrogen, oxygen, and hydrogen with the formula $C_5H_4N_4O_3$; a chemical created when the body breaks down substances called purines

valgus Bowlegged position

valgus stress test A test to evaluate the medial collateral ligament (MCL) in the knee

varus Knock-kneed position

varus stress test A test to evaluate the lateral collateral ligament (LCL) in the knee

vertebra (*pl.,* vertebrae) Any of the separate segments comprising the vertebral column; there are normally 33 of them, differing in size and structure according to location

vertebral foramen The opening in the center of the vertebra through which the spinal cord passes

vesicle A small sac containing fluid

visceral pleura A membrane covering the lungs and lining the inner wall of the chest

$\dot{V}O_2$max Refers to the peak oxygen uptake and the body's ability to use it during exercises that increase in intensity over time

volar Refers to the the palmar surface, or underside of the wrist and hand

volar plate A thick ligament found in the fingers preventing hyperextension injuries

West Point view A specially positioned X-ray view used to detect a Bankart lesion of the shoulder

white matter The portion of the brain containing myelinated nerve fibers; also part of the central nervous system

"winging" Lifting off of the medial border of the scapular shoulder

xerosis A condition in which the skin is abnormally dry

Yergason test A test that is conducted by having the patient flex the elbow and rotate the hand from a palm-down position to a palm-up position while the examiner resists the motion

Zanca view An X-ray view used to evaluate the acromioclavicular (AC) joint in the shoulder

Appendix A

Taping and Bracing Techniques

The step-by-step procedures in this appendix describe the basic taping and bracing techniques used today in sports medicine. The following table lists the various supplies typically used in these procedures.

Table 1 Taping Supplies and Equipment

Type	*Properties*	*Size*	*Brands*	*Uses*
Adhesive spray	Typically aerosol spray that makes the skin more adhesive	Cans come in various sizes of 4 to 12 oz	Tuff Skin	First step before applying any tape or elastic wrap. Always ask about potential allergy before applying
Elastic wraps	Made of cotton with elastic properties	Can vary in size from 2 to 6 in. and length of 5 to 11 yd	Ace Wrap	Can be used for initial injury for compression or used for spicas and wraps to provide support
Adhesive stretch tape	Stretchy tape with adhesive properties to stick to skin or other products such as padding	Can vary from 1 to 4 in. and 2.5 to 5 yd	Powerfast Lightplast	Can be used for compression or to secure padding
Nonadhesive stretch tape	Stretchy tape that sticks to itself	Can vary from 1 to 4 in. and 2.5 to 5 yd	Powerflex Activ-Flex Cohesive stretch tape	Can be used for compression or used as the basis of some tape jobs when prewrap is not needed
Prewrap	Made of foam and provides an under layer before the tape is applied	2¾ in. × 30 yd	Mueller Cramer	Placed under most taping procedures to decrease chafing and blisters
White zinc tape	Nonelastic tape with adhesive properties to stick to skin or other products	Can vary from ½ to 4 in. and 2.5 to 5 yd	Coach Zonas Jaybird Cramer	Used as the primary tape in most procedures due to its nonelastic properties

Note: 1 inch (in.) = 2.54 centimeters; 1 yard (yd) = 0.91 meters; 1 ounce (oz) = 28.35 grams.

This appendix includes discussions of 19 of the most common taping procedures, organized by body region:

1. great toe taping
2. arch taping
3. closed basket weave
4. Achilles taping
5. medial tibial stress syndrome taping
6. McConnell taping
7. knee hyperextension taping
8. medial collateral ligament taping
9. patellar tendinitis strap
10. thigh compression wrap
11. hip spica for adductor strain
12. rib compression wrap
13. shoulder spica for acromioclavicular taping
14. elbow hyperextension tape
15. ulnar collateral ligament taping
16. lateral epicondylitis strap
17. wrist hyperflexion taping
18. buddy taping
19. thumb spica

Great Toe Taping

Great toe taping is applied after injury to the first metatarsophalangeal (MTP) joint of the great toe after a hyperextension or hyperflexion injury and is associated commonly with "turf sports," such as football, soccer, and field hockey. The goal of taping is to limit excessive and/or painful extension or flexion of the MTP joint.

Procedure

Materials. Adhesive spray, 1½-inch (in.; 1 in. = 2.54 centimeters [cm]) white tape, 1-in. white tape.

Positioning and Preparation. The patient is made to lie in the supine position with the knee in extension, foot in relaxed position, and great toe in neutral position. Apply adhesive spray to the foot and great toe where the tape will be applied.

Application

1. Apply an anchor around the midfoot with the 1½-in. white tape. Apply the second anchor with the 1-in. tape around the great toe distally.

1.

2.

2. Apply a fan strip with the 1-in. white tape from the second anchor on the distal great toe. Position the great toe into slight flexion within the painfree range. Secure the first fan strip to the initial anchor. Repeat two to three times with additional fan strips to secure the great toes in painfree position.

3.

3. To secure the fan strips, place the 1½-in. white tape over the initial anchor and the 1-in. white tape over the second anchor.

Final Assessment. Check for circulation and ensure that the application has limited the painful motion and is functional for the athlete.

4.

Additional Notes

4. To limit painful flexion, reverse the fan strips, applying ventrally while placing the great toe in slight extension.

5. To gain additional support for cases of multidirectional instability and/or pain, apply toe spica consisting of two 1-in. white tape strips crossing over the medial MTP joint of the great toe prior to the final anchors. Secure with anchors as described above.

5.

**Custom/Prefabricated Items.* Great toe extension may also be limited by prefabricated steel inserts or a precut plantar fascia strip.

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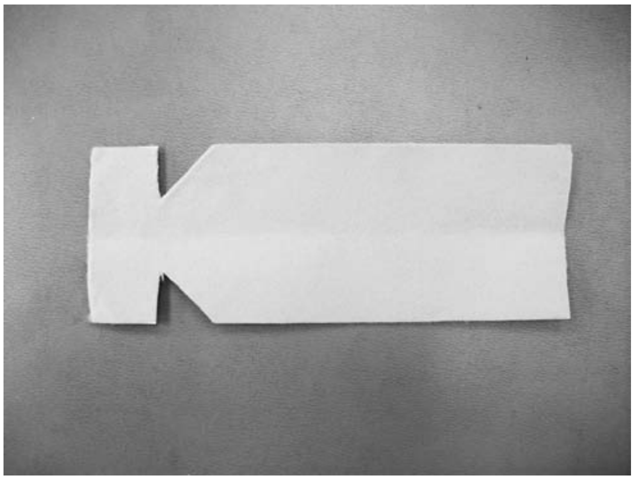

Arch Taping

Arch taping is applied to those individuals who require additional support to their arch in an effort to prevent excessive pronation. With this goal, excessive motion may be limited during gait, and pain in the lower extremity structures irritated by this motion may resolve.

Procedure

Materials. Adhesive spray, 1½-in. white tape, 1-in. white tape.

Positioning and Preparation. The patient is made to lie in the supine position with the knee in extension and the foot in relaxed position. Lightly spray the arch with the adhesive spray, and let it dry.

Application

1. Gently apply a half-anchor of the 1½-in. white tape around the metatarsal heads, pulling from the lateral to the medial direction.

2. Apply the 1-in. white tape in an X pattern with three "Xs" running from the first metatarsal head around the heel and returning to the fifth

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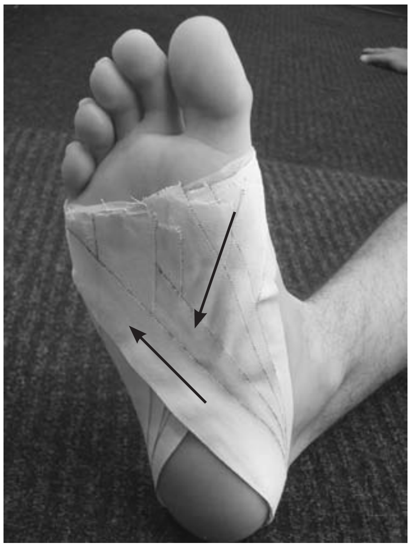

metatarsal head and three “Xs” running from the fifth metatarsal head around the heel and returning to the first metatarsal head. Overlap each “X” while filling in the arch space. Use a minimum of six “Xs” to fill in the entire arch space.

3. Apply the 1½-in. white tape half-anchors, pulling lateral to medial to cover the arch. Anchors should start proximal and continue distally. Be sure to cover all the loose ends.

4. Complete by securing with two full 1½-in. white tape anchors around the metatarsal heads.

Final Assessment. Check for circulation, and ensure that the application has limited the painful motion and is functional for the athlete.

**Custom/Prefabricated Items*. Supporting the arch can also be achieved by purchasing off-the-shelf orthotics or custom shoe inserts.

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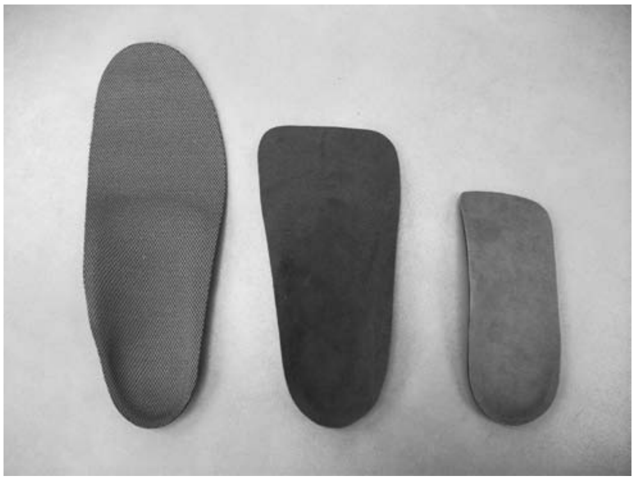

Closed Basket Weave

The closed basket weave is used after an inversion ankle sprain and is one of the most commonly seen tape procedures in sports medicine. It can be used both as a prevention measure and to limit inversion after injury.

Procedure

Materials. Heel and lace pads, adhesive spray, 1½-in. white tape, prewrap.

Positioning and Preparation. The patient is made to lie in the supine position with the knee in extension and ankle in a dorsiflexed position. Lightly spray the ankle with the adhesive spray, and let it dry.

Application

1. Apply at least one heel and lace pad at the front of the ankle and the other at the back where the Achilles tendon inserts into the calcaneus. Secure the pads with the prewrap, and cover the area where the tape will be applied.

2. Apply one anchor of the 1½-in. white tape 6 in. above the malleoli, adhering the prewrap to the skin. The second anchor should be placed around the midfoot while avoiding direct compression of the base of the fifth metatarsal.

3. Apply a stirrup running from the medial to lateral direction, from the medial proximal anchor to the lateral side, extending just above the anchors on both sides; this should cover the posterior one third of the malleoli. Apply the first

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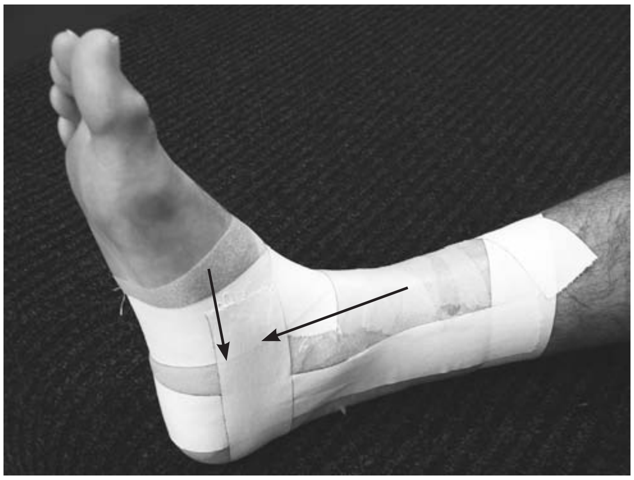

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horseshoe starting directly on the metatarsal anchor along the first metatarsal, traveling behind the heel, and ending along the fifth metatarsal. Apply horseshoes always from the medial to lateral direction unless your goal is to limit eversion, in which case the pull would be in the opposite direction.

4. Apply each additional stirrup in the same fashion while overlapping by half the width of the tape. The second stirrup should cover the middle one third of the malleoli, with the third stirrup covering the anterior one third. Apply horseshoe strips in the same manner, with each strip slightly shorter than the previous, leaving a staircase appearance. Apply the stirrups and the horseshoes in an alternating fashion.

5. Follow the third horseshoe up the leg until you have completely enclosed the ankle and have ended just past your initial anchor. These strips should continue to be applied by overlapping half the width of the tape. Apply additional arch support until the bottom is enclosed.

6. Start applying the tape on the lateral malleolus, and pull around the arch of the foot to begin a figure-eight pattern.

4.

5.

6.

7. Continue the figure-eight pattern by completing a full turn around the ankle so that the roll of tape ends on the medial side, moving downward toward the medial malleolus.

8. From this position, direct the roll of tape to the outside of the heel, and apply a heel lock, ending with the roll of tape moving in a caudal position.

9. Continue by pulling the tape up and around the ankle with a complete turn.

7.

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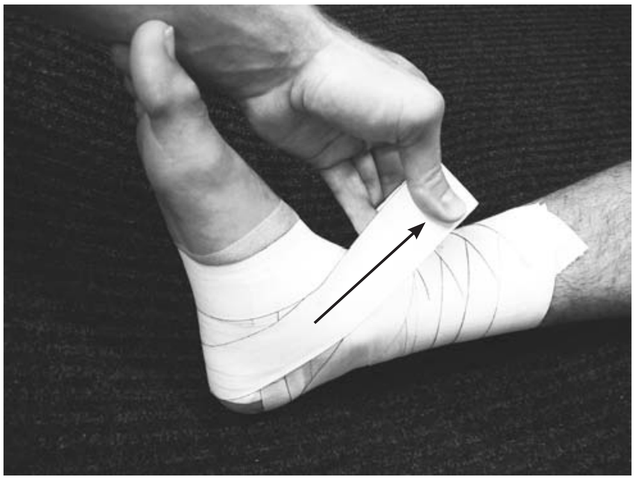

9.

10. Once around the ankle, continue along the lateral ankle, moving toward the medial side of the heel, and apply another heel lock.

11. Once around the ankle, the tape may finish anywhere. Additional figure-eight and heel locks may be added depending on the severity of the injury or the size of the athlete.

Final Assessment. Check for circulation, and ensure that the application has limited either the painful motion or the inversion and is functional for the athlete.

**Custom/Prefabricated Items.* A number of ankle braces can be purchased with the benefits of self-application and increased cost-effectiveness.

10.

11.

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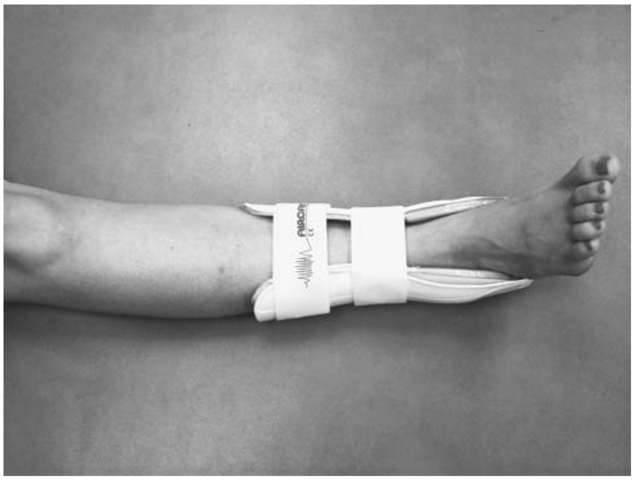

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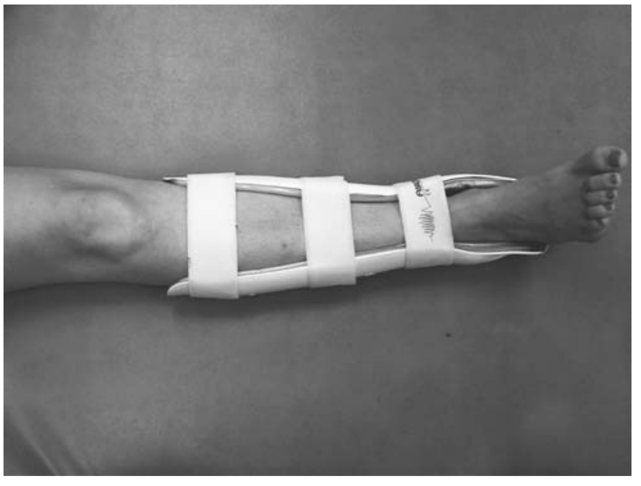

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Achilles Taping

Achilles taping is applied to those individuals who suffer from pain with plantarflexion and where additional support and help with this motion are required. The goal of this tape job is to assist in the motion of plantarflexion and alleviate pain and discomfort.

1.


2.


Procedure

Materials. Prewrap, adhesive spray, 1½-in. white tape, 3-in. heavy-duty tape.

Positioning and Preparation. The patient is made to lie in the prone position with the knee in extension and the foot in relaxed position, slightly plantarflexed. Lightly spray the foot and ankle with the adhesive spray.

Application

1. Apply the prewrap around the foot, ankle, and lower leg. Apply an anchor of the 1½-in. white tape around the metatarsal heads and the other anchor 6 in. above the malleoli. Starting dorsally on initial anchor, apply the 3-in. heavy-duty stretch tape running to the anchor on the lower leg while the foot maintains a relaxed position. The first strip should run in a straight fashion.

2. Apply two additional 3-in. heavy-duty stretch tape strips with each crossing over the painful site to form an X pattern.

3. Cover the anchors with the 1½-in. white tape, ensuring that there are no loose ends.

Final Assessment. Check for circulation, and ensure that the application has limited the painful motion and is functional for the athlete.

3.

Medial Tibial Stress Syndrome Taping

Medial tibial stress syndrome (MTSS) or shin splint taping is applied to those individuals who suffer from pain in their lower leg during activity. Also known as an *open spiral*, the goal of this taping is to compress the musculature of the anterior lower leg to alleviate pain.

Procedure

Materials. Adhesive spray, 1½-in. white tape.

Positioning and Preparation. The patient is made to lie in the supine position with the knee in extension and foot in relaxed position. Lightly spray the lower leg with the adhesive spray, and let it dry.

Application

1. Apply a strip of the 1½-in. white tape starting laterally, or opposite to the painful side and 2 in. below. Wrap the tape around lower leg while squeezing the Achilles tendon, and end the strip just past the starting point. Always pull the tape so that the painful area moves toward the tibia.

2. Continue to apply additional strips in the same fashion. Be sure to overlap

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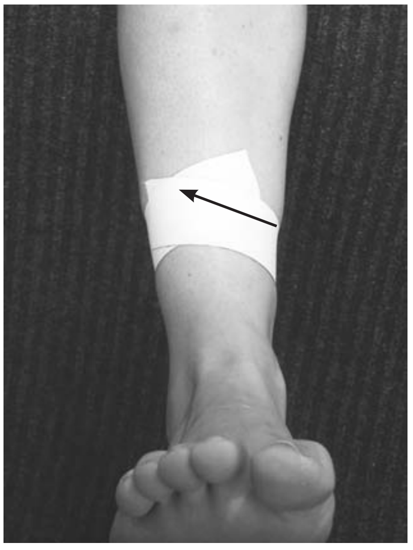

2.

half of the previous strip. Each strip is applied tightly. Continue strips application until you are 2 in. above the painful site. Each individual strip should overlap and enclose the previous strip. Complete by applying a full anchor on both proximal and distal ends.

Final Assessment. Check for circulation, and ensure that the application causes limited pain and is functional for the patient.

**Custom/Prefabricated Items*. A number of commercial compression sleeves are available that re-create the same effect.

*

McConnell Taping

McConnell taping is applied typically to treat patellofemoral stress syndrome (PFSS), which typically occurs with abnormal tracking of the patella. The goal of taping the patella is to restore proper tracking mechanics of the patella and to decrease or relieve painful knee biomechanics.

Procedure

Materials. Adhesive spray, 2-in. coverall, 1½-in. leukotape, scissors.

Positioning and Preparation. Check the skin for wounds and irritation. Remove excessive hair with a razor. The patient should be made to lie in the supine position on a table with the knee fully extended; the quadriceps should be fully relaxed to allow patella mobility. Apply adhesive spray to the knee where the tape will be applied, and allow it to dry.

Application

1. Cut strips of coverall long enough to cover the patella and the medial knee. Then apply these strips as a base covering the patella and medial knee.

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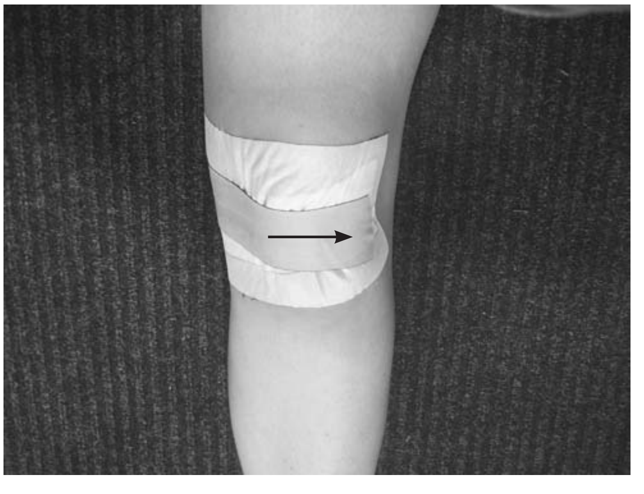


2. To limit lateral tracking, apply a strip of leukotape laterally on the patella, then pulling medially and placing the other end over the medial knee. Cut off the excess tape.

3. Apply two or three more strips as described above, covering the patella.

Final Assessment. Check the range of motion (ROM) of the knee and the comfort of the tape. Ensure that the application has limited the painful motion and is functional for the patient.

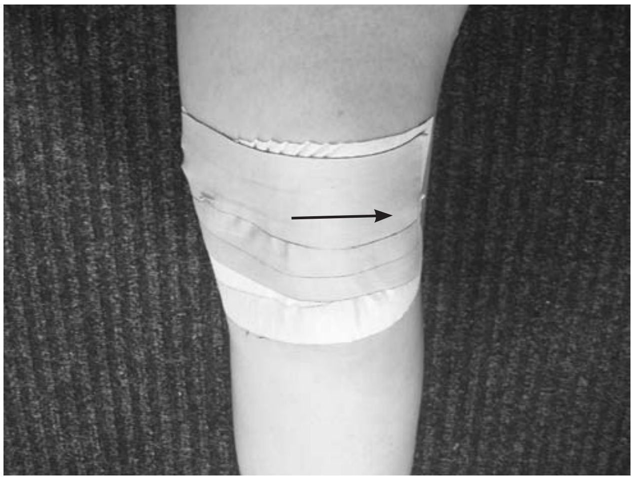
Additional Notes

4. To ensure that the tape will remain on and not fall off prematurely during activity, you may wrap it with nonadhesive stretch tape.

5. To limit tilting in other directions, pull the leukotape in the opposite direction of the motion that you are trying to limit.

**Custom/Prefabricated Items.* Abnormal patella tracking can also be altered by using a commercial brace with a patella buttress.

3.



4.

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Knee Hyperextension Taping

Knee hyperextension taping is applied when a knee hyperextension injury has occurred. The goal of this tape job is to limit painful knee extension.

Procedure

Materials. Adhesive spray, prewrap, 2-in. heavy-duty elastic tape, 3-in. adhesive elastic tape, scissors.

Positioning and Preparation. Check the skin for wounds and irritation. The patient should be standing with the affected knee flexed 25° to 35° or within a painfree ROM. The patient should have a good portion of his or her weight over the affected leg and with the quadriceps contracted so that the wrap is not too tight. Apply adhesive spray to the lower leg and thigh where the tape will be applied.

Application

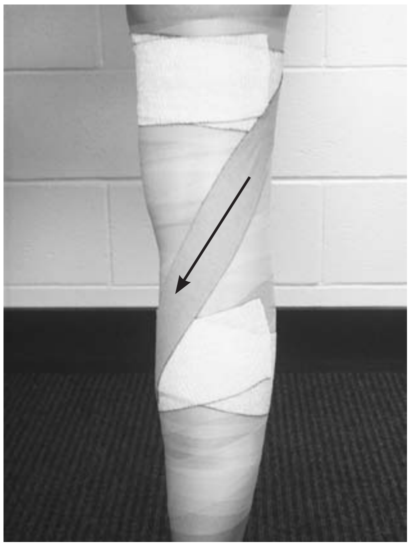
1. Apply the prewrap over the entire area that will be taped, starting at the midthigh and continuing distally to the midgastrocnemius. (*Note:* The longer the level of the tape job, the more effective it will be in preventing painful ROM.) Apply two anchors with the 3-in. adhesive elastic tape over the prewrap, one on the midthigh and the other on the midgastroc.

2. Apply strips of the 2-in. heavy-duty elastic tape in an X pattern behind the knee. The first strip should be applied laterally on the thigh anchor, crossing the posterior knee and ending at the medial anchor on the gastrocnemius. Cut off the excess heavy-duty elastic tape.

3. The second strip is applied medially on the thigh anchor, crossing the posterior knee and ending on the

1.

2.



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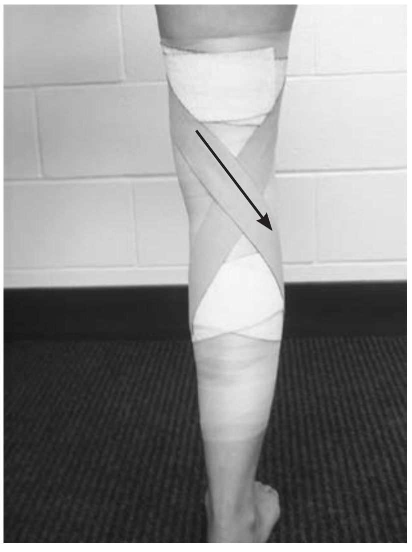


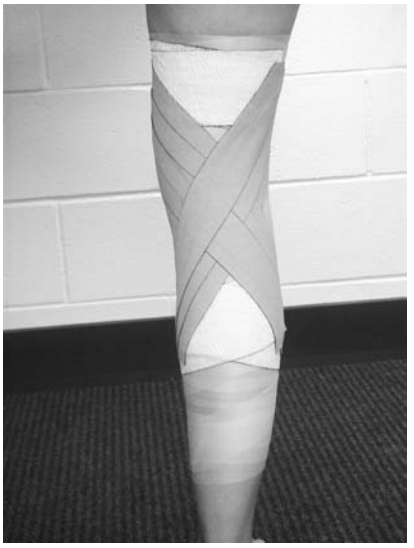
lateral anchor on the gastroc. Cut off the excess heavy-duty elastic tape.

4. Apply two more strips as described above, creating an X pattern behind the knee.

5. Cover the distal anchors up to the tibial tuberosity with the 3-in. adhesive stretch tape. Cover the proximal anchors distally with the 3-in. adhesive stretch tape, ending 3 in. above the superior patella. *Note:* To ensure normal tracking of the patella, do not cover the patella with the tape.

Final Assessment. Check the ROM of the knee and the comfort of the tape. Ensure that the application has limited the painful motion of the knee and is functional for the athlete.

4.



5a.

5b.

**Custom/Prefabricated Items.* Off-the-shelf braces with an ROM lock can limit the painful ROM—such as a knee immobilizer.

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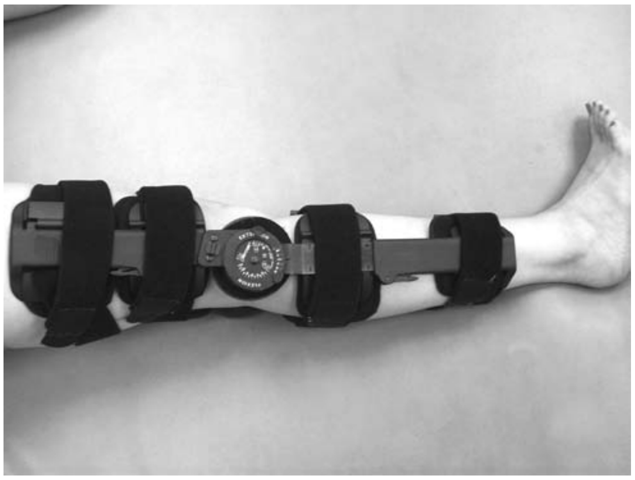


Medial Collateral Ligament Taping

Collateral ligament taping is applied when either the medial collateral ligament (MCL) or the lateral collateral ligament (LCL) is sprained. The goal of this tape job is to protect the ligament from further injury.

Procedure

Materials. Adhesive spray, prewrap, 1½-in. white tape, 3-in. adhesive elastic tape.

Positioning and Preparation. Check the skin for wounds and irritation. The patient should be standing with the affected knee slightly flexed and within a painfree ROM. The patient should have a good portion of his or her weight over the affected leg and with the quads contracted so that the wrap is not too tight. Apply adhesive spray to the knee and thigh where the tape will be applied.

Application

1. Apply the prewrap over the entire area that will be taped; starting at the upper thigh and continuing down to the midgastrocnemius. Apply two anchors with the 3-in. adhesive elastic tape on the upper thigh and midgastroc.
2. Apply strips of the 1½-in. white tape in an X pattern over the MCL.

1.

2.

The first strip will be applied on the anterior thigh anchor, crossing the medial joint line and ending at the posterior anchor on the gastrocnemius.

3. The second strip will be applied on the posterior thigh anchor, crossing the medial joint line and ending on the anterior anchor on the gastroc.

3.

4. Apply two or three more strips as described above, creating an X pattern over the medial joint line.

4.

5. Cover the distal anchors up to the tibial tuberosity with the 3-in. adhesive stretch tape. Cover the proximal anchors distally with the 3-in. adhesive stretch tape ending 3 in. above the superior patella. *Note:* Do not cover the patella with the tape, to ensure normal tracking of the patella.

5.

Final Assessment. Check the ROM of the knee and the comfort of the tape. Ensure that the application is functional for the patient and gives support to the MCL.

Additional Notes

To tape for an LCL sprain, follow the previous steps, with the X pattern applied over the LCL.

Custom/Prefabricated Items. Off-the-shelf braces with a medial stabilizer can be applied.

*

Patellar Tendinitis Strap

A patellar tendinitis strap is applied for a patient suffering from patella tendinitis (jumper's knee) or Osgood-Schlatter disease. The goal of this tape job is to decrease pain by applying pressure to the tendon and decreasing the stress of the tendon on the tibial tuberosity, where it inserts.

Procedure

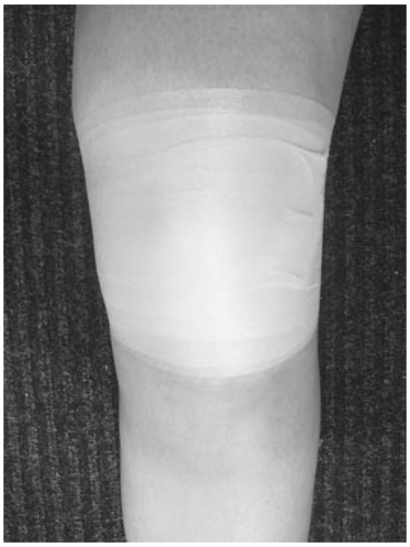
Materials. Prewrap, 1½-in. white tape.

Positioning and Preparation. Check the skin for wounds and irritation. The patient should be standing with the affected knee slightly flexed and within a painfree ROM.

Application

1. Apply the prewrap, encircling the knee over the patella six to eight times with equal tension.
2. Apply three strips of the 1½-in. white tape anteriorly in the center of the prewrap.

1.



2.

3. Roll the prewrap and tape from the proximal to distal direction to create a strap. Place the strap over the patellar tendon.

Final Assessment. Check the ROM of the knee and the comfort of the tape. Ensure that the application has adequate pressure on the patellar tendon and is functional for the patient.

**Custom/Prefabricated Items*. Jumper's knee straps can be purchased over the counter to re-create this tape job.

3a.

3b.

*

Thigh Compression Wrap

A thigh compression wrap may be applied after an injury such as a contusion or muscle strain to either the hamstring or the quadriceps muscle group. The goal of this wrap is to compress the muscle group and the origin of pain while providing support.

Procedure

Materials. Adhesive spray, 6-in. single elastic bandage, 1½-in. white tape. *Note:* Depending on the size of the patient, you may have to use a larger elastic wrap, 6 in. × 5 yards (yd), 6 in. × 11 yd, or 4 in. × 11 yd (1 in. = 2.54 cm; 1 yd = 0.91 meters [m]).

Positioning and Preparation. The patient should be standing with the involved knee flexed between 20° and 30° while keeping the majority of the patient's weight on the involved side. Apply spray on the area to be wrapped, and allow it to dry.

Application

1. Begin distal to the site of pain, and apply the compression wrap around the area to be treated in a herringbone fashion with the "Xs" central over the site of pain.
2. Continue proximally overlapping the compression wrap by half the width of the wrap.
3. Secure the wrap with the 1½-in. white tape by placing an "X" over the painful area, and anchor at the top and bottom.

Final Assessment. Check for circulation, and ensure that the application has limited the painful motion and is functional for the athlete.

1.

2.

3.

**Custom/Prefabricated Items.* Commercial compression sleeves, both with and without additional padding, are available.

*

Hip Spica for Adductor Strain

A hip spica may be used for a number of conditions, including support of the adductor and hip flexor groups in addition to securing padding after an injury to the hip bone, or "hip pointer." The goal of this supportive wrap is to compress the muscle group and origin of pain while providing support and aiding in the natural motion of the muscle group.

1.

Procedure

Materials. Adhesive spray, 4-in. double-elastic bandage, 1½-in. white tape. *Note:* Depending on the size of the patient, you may have to use a larger elastic wrap, such as 6 in. × 11 yd.

Positioning and Preparation. The patient should be standing with the involved leg placed in an internally rotated position. Ask the athlete to assume a slightly forward-lunge position that flexes the knee and causes the hip to adduct. Gently spray the thigh area that will be wrapped, which acts as the anchor for this tape procedure. *Note:* For maximum support, have the athlete wear spandex or tight shorts so that the wrap can be as close to the body part as possible.

Application

1. Secure the wrap to the leg by anchoring the wrap around the thigh while pulling laterally to medially.

2. Continue wrapping up and around the trunk, crossing deep in the groin over the adductor muscle group.

3. Finish the wrap on the thigh, and secure with the 1½-in. white tape by tracing the pattern once around the thigh and trunk. Add more tape strips as needed.

4. To secure the wrap further, you can trace the pattern of the wrap with the 3-in. adhesive elastic tape.

Additional Notes

To provide supportive taping for the hip flexor, begin in a similar fashion to the hip adductor wrap but with the patient in a slightly forward-lunge position with a slight forward bend at the trunk. Pull the wrap from medial to lateral, and place an "X" over the site of pain or the hip flexor group.

Custom/Prefabricated Items. Commercial compression garments can be purchased that offer focal and general compression.

2.

3.

4.

Rib Compression Wrap

A rib compression wrap is used to relieve the pain of a rib fracture or intercostal strain, secure a protective pad over an injured site, or control swelling. The goal of the wrap is to provide support to the injured area and decrease pain.

Procedure

Materials. Adhesive spray, 4-in. × 5-yd elastic wrap, 1½-in. white tape. *Note:* Depending on the size of the patient, you may have to use a larger elastic wrap, 6 in. × 5 yd, 6 in. × 11 yd, or 4 in. × 11 yd.

Positioning and Preparation. Check the skin for wounds and irritation. The patient should be standing with the arms abducted. Apply adhesive spray to the torso where the elastic bandage will be applied.

Application

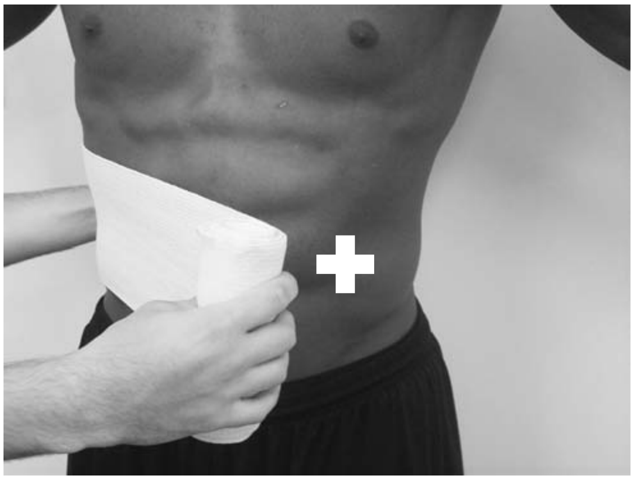
The procedure described below is for a rib fracture. The injured area is marked "+."

1. Start the wrap superiorly to the injured site, encircling the torso and overlapping about 2 in. each time around.

2. Work your way caudally, covering the injured site and ending over the wrap superiorly to the injured area.

3. Apply two to three strips of the 1½-in. white tape at the end of the wrap to secure it.

1.



2.

3.

4. To secure the wrap, you may encircle the wrap and tape with the 3-in. adhesive elastic tape.

Final Assessment. Check the ROM of the torso and the comfort of the athlete during respiration. Ensure that the application provides support to the injured site and is functional for the athlete.

**Custom/Prefabricated Items.* Rib belts can be purchased off the shelf to obtain similar results.

4.

*

Shoulder Spica for Acromioclavicular Taping

The acromioclavicular (AC) wrap may be applied after an injury to the AC joint from direct contact, such as tackling in football or forced horizontal adduction. The goal of this wrap is to provide protection and general compression to the AC joint and shoulder in general.

1.

Procedure

Materials. Adhesive spray, compression wrap (various widths and lengths), 1½-in. white tape.

Positioning and Preparation. The patient should be placed in a standing or seated position with the involved arm at the side and the hand on the hip.

Spray the humerus with the adhesive spray, as this will act as the anchor for this tape procedure.

2.

Application

1. Begin wrapping the midhumerus in a clockwise fashion (lateral to medial), and continue in a spiral fashion while overlapping by half the width of the wrap, moving distal to proximal for at least two times around the humerus.

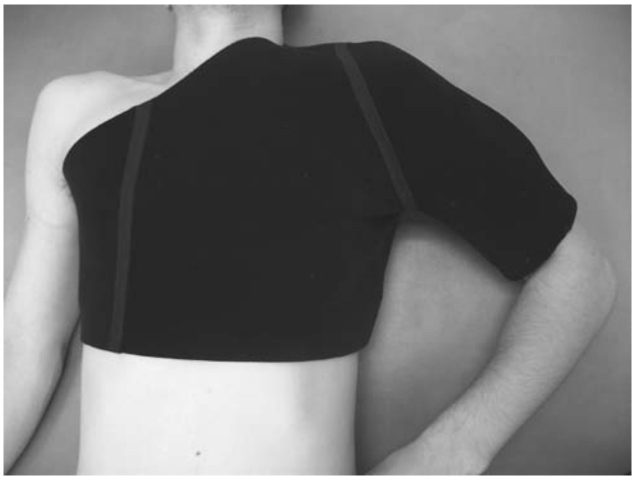
2. Pull medially across the chest and under the opposite axilla, and continue around the torso. Apply the greatest amount of tension over the shoulder and the least amount of tension as you wrap around the torso. Encircle the humerus again.

3.

3. Repeat the pattern at least twice or as needed depending on the size of the patient and the support needed. End the wrap on the arm. Secure the wrap with the 1½-in. tape by tracing the pattern on the humerus.

Final Assessment. Check for circulation, and ensure that the application has limited the painful motion and is functional for the athlete.

*



Additional Notes

In association with many AC joint injuries, an "AC pad" is often applied directly over the AC joint to provide padding to the injured joint below. Apply the AC pad if needed prior to securing the AC wrap.

**Custom/Prefabricated Items*. Other commercial items that are commonly used to support the shoulder either after injury or during actual play include the Sully Stabilizing Brace.

Elbow Hyperextension Tape

Elbow hyperextension taping is very similar to the knee hyperextension taping technique. This is applied when an elbow hyperextension injury has occurred, with the goal of limiting painful extension.

Procedure

Materials. Adhesive spray, prewrap, 2-in. heavy-duty adhesive elastic tape, 3-in. adhesive elastic tape, scissors.

Positioning and Preparation. Check the skin for wounds and irritation. The patient should have the affected elbow in slight flexion within a painfree range and supinated. Apply adhesive spray to the forearm and humerus where the tape will be applied.

Application

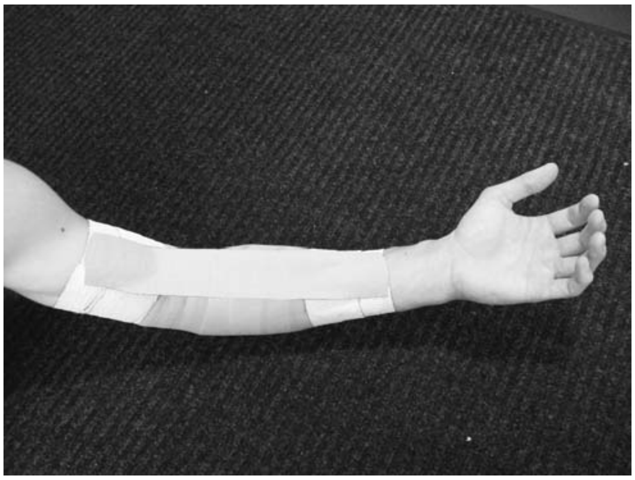
1. Apply the prewrap over the entire area that will be taped; starting at the midhumerus and continuing distally to the midforearm. (*Note:* The longer the level of the tape job, the more effective it will be in preventing painful ROM.) Apply two anchors with the 3-in. adhesive elastic tape, one on the midhumerus and the other at the midforearm.

2. Apply a strip of the 2-in. heavy-duty adhesive elastic tape over the anterior elbow. The first strip will begin on the anterior anchor of the humerus and follow the midline of the humerus distally to the forearm, where it ends at the second anchor at the midforearm. Cut off the excess heavy-duty elastic tape.

3. The next two strips will create an X pattern over the anterior elbow. The second strip will be applied laterally on the distal humeral anchor, crossing the anterior elbow and ending at the medial anchor on the forearm (ulna). The third strip will be applied medially on the

1.

2.



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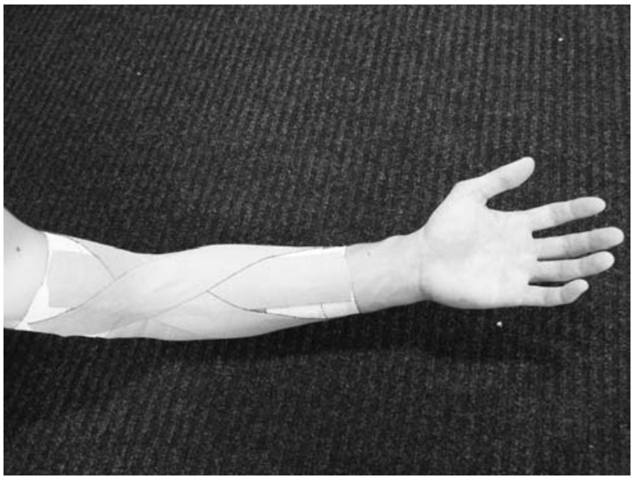


distal humeral anchor, crossing the anterior elbow and ending at the lateral anchor on the forearm (radius). Cut off the excess heavy-duty elastic tape.

4. Cover the tape job with the 3-in. adhesive elastic tape. *Note:* Do not cover the olecranon process with the tape, to ensure ease of movement.

Final Assessment. Check the ROM of the elbow to make sure that it is within the painfree ROM and functional for the patient. Check the distal capillary refill and the comfort of the tape for the patient.

**Custom/Prefabricated Items.* Off-the-shelf braces with an ROM lock can limit the painful motion of the elbow.

4.

*

Ulnar Collateral Ligament Taping

This taping procedure is similar to the collateral ligament taping of the knee. Collateral ligament taping is applied when either the ulnar collateral ligament (UCL) or the radial collateral ligament (RCL) is sprained. The goal of this tape job is to protect the ligament from further injury.

Procedure

Materials. Adhesive spray, prewrap, 1½-in. white tape, 3-in. adhesive elastic tape.

Positioning and Preparation. Check the skin for wounds and irritation. The patient should be standing with the

1.

affected elbow slightly flexed within a painfree ROM and supinated. Apply adhesive spray to the forearm and humerus where the tape will be applied.

Application

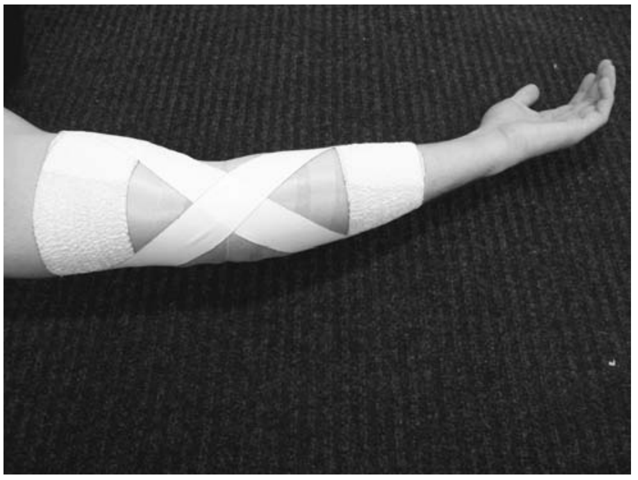
1. Apply the prewrap over the entire area that will be taped, starting at the midhumerus and continuing distally to the midforearm. Apply two anchors with the 3-in. adhesive elastic tape over the prewrap, one on the midhumerus and the other on the midforearm.

2. Apply strips of the 1½-in. white tape in an X pattern over the UCL. The first strip will be applied on the anterior humeral anchor, crossing the medial joint line and ending at the posterior anchor on the forearm.

3. The second strip will be applied on the posterior humeral anchor, crossing the medial joint line and ending on the anterior anchor on the forearm.

2.

3.



4. Apply two or three more strips as described above, creating an X pattern over the UCL.

4.

5. Cover the tape job with the 3-in. adhesive elastic tape. *Note:* Do not cover the olecranon process with the tape, to ensure ease of movement.

5.

Final Assessment. Check the distal capillary refill and the comfort and function of the tape for the patient.

Additional Notes

To tape for an RCL sprain, follow the previous steps but with the X pattern applied over the RCL.

**Custom/Prefabricated Items*. There are various off-the-shelf braces that can be purchased that will re-create the function of the tape procedure for the UCL.

*

Lateral Epicondylitis Strap

A lateral epicondylitis strap is used for a patient suffering from lateral epicondylitis (tennis elbow). The goal of this tape job is to decrease pain by applying pressure to the common extensor bundle to decrease the stress of the extensor muscles on the bony attachment.

Procedure

Materials. Prewrap, 2-in. adhesive elastic tape, 1½-in. white tape.

Positioning and Preparation. Check the skin for wounds and irritation. The patient's arm should be in a relaxed supinated position.

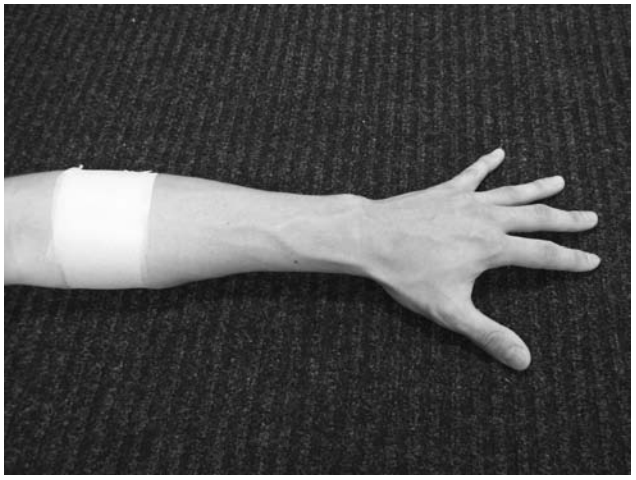
Application

1. Apply the prewrap around the elbow two to three times distal to the lateral epicondyle, approximately ½ in.

2. Apply six strips of the 1½-in. white tape in the center of the prewrap distal to the lateral epicondyle.

3. Cover the prewrap and the 1½-in. white tape strips with the 2-in. adhesive elastic tape.

1.



2.

3.

Final Assessment. Check the distal capillary refill and the comfort and function of the tape for the patient.

**Custom/Prefabricated Items*. Prefabricated lateral epicondylitis straps can be purchased over the counter.

*

Wrist Hyperflexion Taping

Taping to the wrist is applied after an injury to any of the carpal bones or the wrist in general or to limit painful motion. The goal of this tape job is to provide stability and limit painful motions about the wrist to allow it to be used in athletic participation.

Procedure

Materials. Adhesive spray, 1½-in. white tape, prewrap.

Positioning and Preparation. Place the patient's wrist in a neutral position with the fingers abducted. Spray the area to be wrapped, and apply the prewrap as needed.

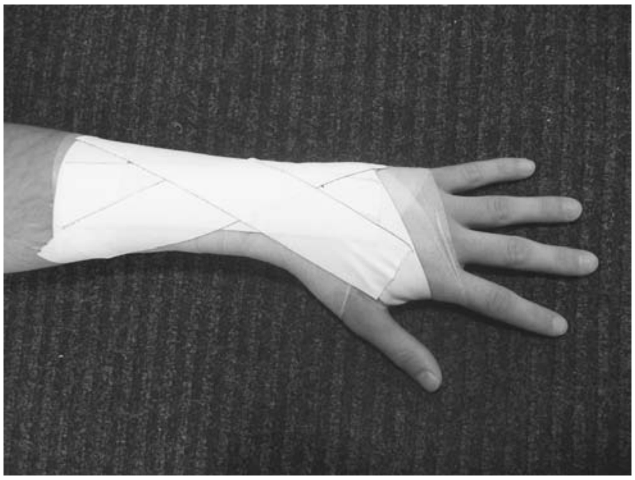
Application

1. Begin by applying two anchors on the midforearm and one around the hand just proximal to the metacarpophalangeal (MCP) joints. Be sure to keep the MP joints uncovered while slightly folding the tape before it crosses the thumb crease.

1.

2. Apply parallel strips starting at the anchor on the hand and running to the anchor on the forearm. Complete

2.



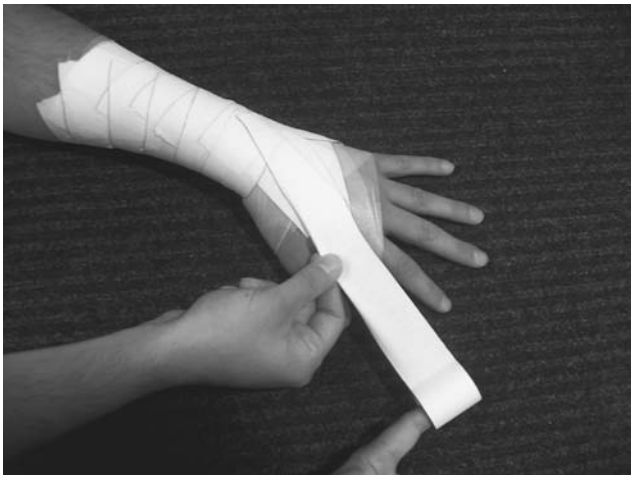
by applying at least two "Xs" in a similar fashion, crossing over the carpals. Apply parallel strips and "Xs" to the opposite side. If needed, add additional strips to the side in which you intend to limit the most motion (the dorsal side to prevent flexion and ventral side to prevent extension).

3. Close the entire forearm with the anchors.

4. Apply two figure-eight patterns starting on the dorsal side at the ulnar styloid process. Pull the tape between the thumb and the index finger, making sure that you place a small fold in the tape as it crosses through.

3.

4a.



4b.

5. Continue to pull the tape across the palm to the dorsal side of the hand.

6. Continue to pull around the wrist, and end on dorsal side of the wrist. Repeat as necessary.

Final Assessment. Check for circulation and ensure that the application has limited the painful motion and is functional for the athlete.

**Custom/Prefabricated Items.* Various prefabricated splints are available, such as the wrist splint. The velcro allows effortless application by the patient.

5.

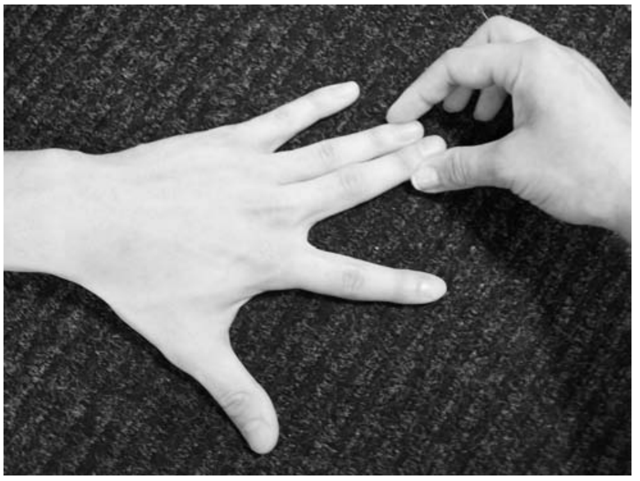
6.

*

Buddy Taping

Buddy taping is the easiest and most common taping procedure for a patient to apply. It is typically used when an interphalangeal (IP) joint has been sprained. The goal of this tape job is to use one digit as a support for the injured digit to protect the sprained IP joint from further injury.

1.



2.

3.

Procedure

Materials. Adhesive spray, 1-in. white tape.

Positioning and Preparation. Check the skin for wounds and irritation. The patient's hand should be relaxed and placed in a painfree position. Apply adhesive spray to the digits where the tape will be applied.

Application

The following taping procedure is for a sprained proximal IP of the fourth digit. For any other digits, simply repeat the steps as indicated.

Additional Notes

This is typically a procedure for a sprain in the second to fifth digits; this procedure is not used for the first digit. For a sprained first digit, see the section Thumb Spica.

1. Place the third digit next to the fourth digit in a comfortable, painfree ROM.

2. Apply a strip of the 1-in. white tape to encircle the proximal phalanges of the third and the fourth digits.

3. Apply a second strip of the 1-in. white tape to encircle the middle

phalanges of the third and the fourth digits.

Final Assessment. Check the distal capillary refill of the third and fourth digits. Ensure that the tape is giving support to the fourth digit and is functional for the patient.

**Custom/Prefabricated Items*. Various prefabricated splints are available, such as the aluminum finger splints and the Stax plastic finger splints.

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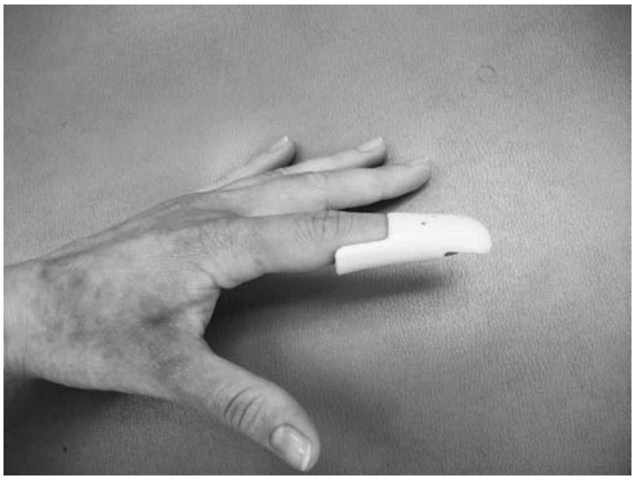

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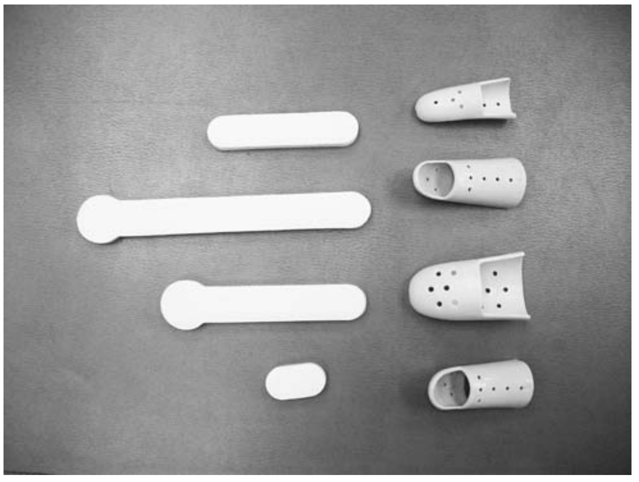

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Thumb Spica

The thumb spica is used when the MCP joint of the first digit has been sprained. The goal is to limit multidirectional instability and prevent painful motion.

Procedure

Materials. Adhesive spray, prewrap, 1-in. white tape, 1½-in. white tape.

Positioning and Preparation. Check the skin for wounds and irritation. The patient should be relaxed, with his or her thumb slightly abducted and extended into a painfree position. Apply the adhesive spray to the first digit and the distal wrist where the tape will be applied.

Application

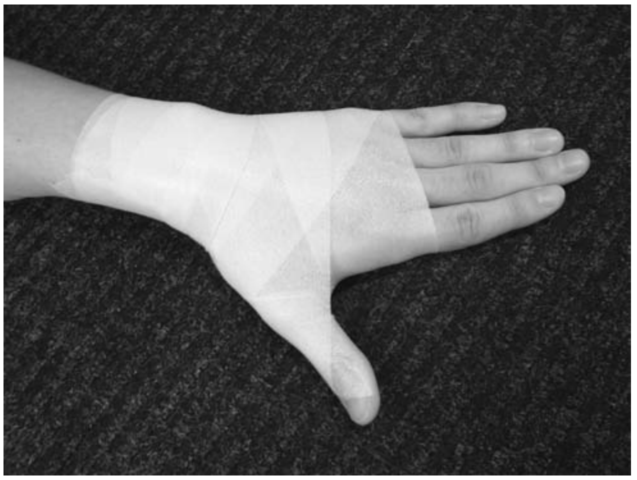
The following procedure is for a hyperflexion injury to the MCP of the first digit. To prevent hyperextension of the joint, follow the steps below, but place the X pattern on the volar aspect of the thumb.

1. Cover the thumb, the proximal hand, and the distal wrist with the prewrap.

2. Place two anchors with the 1½-in. white tape encircling the wrist.

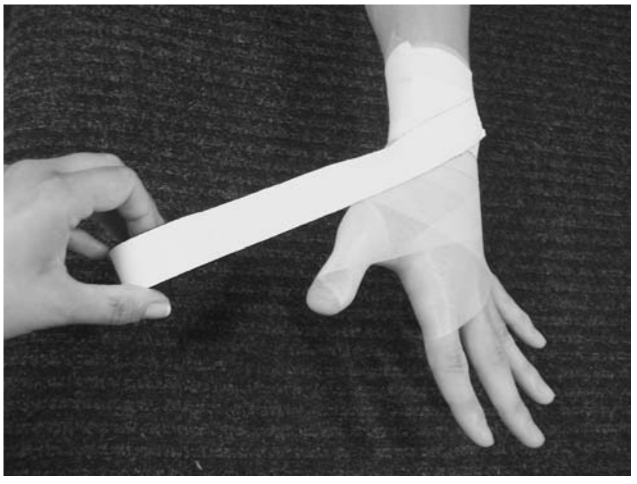
3. Begin a strip of tape on the dorsal aspect of the anchors on the distal wrist. Continue this strip distally, crossing the lateral joint line of the MCP joint of the first digit.

1.



2.

3.



4. Continue the tape around the joint, crossing over the posterior aspect of the MCP joint of the first digit and ending on the volar aspect of the anchor on the wrist. You should have created an X pattern on the dorsal aspect of the MCP joint of the first digit.

5. Apply one or two more strips as indicated above, moving more distally on the first digit. *Note:* Do not cross the IP joint of the first digit.

6. Cover the anchors on the wrist with the 1½-in. white tape.

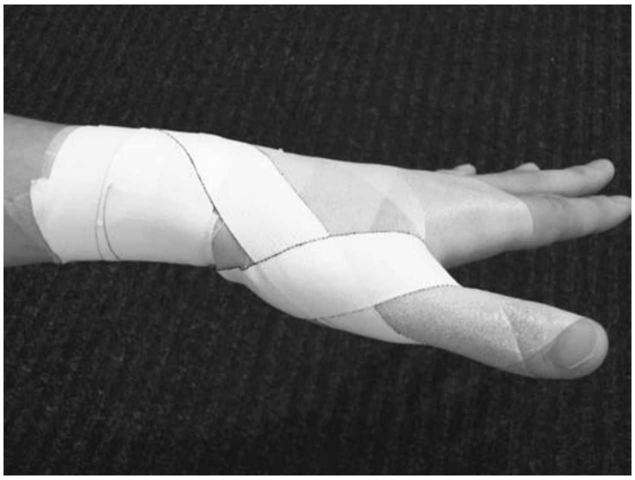
Final Assessment. Check the distal capillary refill of the first digit. Ensure that the tape prevents painful hyperflexion and is functional for the patient.

Additional Notes

Use caution when removing the tape from the first digit, so as to prevent damage to the distal phalanx; removing the tape with scissors is recommended.

4a.

4b.



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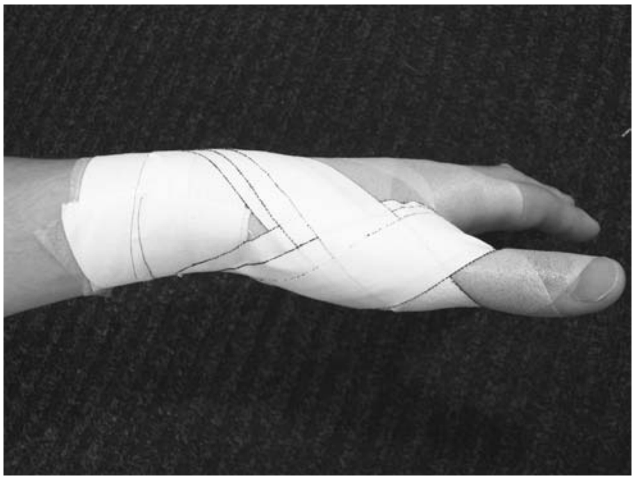

**Custom/Prefabricated Items.* Prefabricated thumb braces can be purchased to obtain similar results.

6.

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Conclusion

Just as all medical procedures have evolved, so too has the advancement of both taping and bracing applications. Although taping after the initial injury is rare, taping and bracing for support and protection during athletic participation and activities of daily living is a well-established practice that continues to undergo refinement based on sound knowledge and the practical experience of trained practitioners.

Arthur Horne and Cheryl Blauth

Further Readings

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Appendix B

Organizations

Health, Fitness, and Safety

American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD)

Website: http://www.aahperd.org
Publications: *Research Quarterly, Health Education*; *Journal of Physical Education, Recreation and Dance*

An alliance of associations providing support to professionals involved in physical education, recreation, fitness, sports and coaching, dance, and health education and promotion.

American Association for Physical Activity and Recreation (AAPAR)

Website: http://www.aahperd.org/aapar

An association linking professionals in education with community-based programs, promoting creative and active lifestyles through physical activity and recreation across the life span.

American Council on Exercise (ACE)

Website: http://www.acefitness.org

A nonprofit organization that protects against ineffective fitness products, while also providing ongoing public education, outreach, and research, and sets certification and continuing education standards for fitness professionals.

American School Health Association (ASHA)

Website: http://www.ashaweb.org

An association that organizes and advocates for effective school health policies that contribute to optimal health and academic outcomes for all school-age children.

American Sport Education Program (ASEP)

Website: http://www.asep.com

An organization providing an educational program for coaches based on sports sciences such as sport physiology, sport psychology, and sport biomechanics.

American Swimming Coaches Association

Website: http://www.swimmingcoach.org
Publication: *Journal of Swimming Research*

A swimming association dedicated to enhancing coaching and building a stronger swimming community.

Canadian Fitness Professionals (CAN-FIT-PRO)

Website: http://www.canfitpro.com

An organization providing education and certification for fitness professionals throughout Canada.

Cooper Institute for Aerobics Research

Website: http://www.cooperaerobics.com

A nonprofit, founded in 1970, that has established an international reputation for research and education in preventive medicine.

Exercise Safety Association (ESA)

Website: http://www.exercisesafety.com

A national organization for fitness professionals providing certification and membership as well as fitness instructor training.

International Fitness Professionals Association (IFPA)

Website: http://www.ifpa-fitness.com

An association affiliated with Doctors Fitness Centers (DFC) and the Fitness Institute of Technology (FIT), providing fitness professionals the education and certification necessary to treat more than 65 different diseases, disabilities, and dysfunctions.

Joint Commission on Sports Medicine and Medical Science

Website: http://www.jcsportsmedicine.org

A voluntary forum that meets annually to discuss current issues in the profession as well as those that concern the future of sports medicine.

National Alliance for Youth Sports (NAYS)

Website: http://www.nays.org

An organization whose aim is to make the sports experience safe, fun, and healthy for youth by ensuring that the adults involved have proper training and information.

National Association for Health & Fitness (NAHF)

Website: http://www.physicalfitness.org

A nonprofit organization that promotes physical fitness, sports, and healthy lifestyles by fostering and supporting governors' and state councils and coalitions that promote and encourage regular physical activity.

National Association of Speed and Explosion (NASE)

Website: http://www.naseinc.com
Publication: *Sportspeed*

An educational organization and certification agency that includes coaches, strength and conditioning coaches, personal trainers, educators, and physicians focusing on the improvement of speed in short sprints to enhance athletic performance.

National Athletic Trainers' Association, Inc. (NATA)

Website: http://www.nata.org
Publication: *Athletic Training Journal*

A professional membership association for certified athletic trainers geared toward enhancing and advancing the athletic training profession.

National Council of Youth Sports (NCYS)

Website: http://www.ncys.org

An organization that represents more than 185 organizations (44,000,000 youth in organized sports) in the youth sports industry and promotes physical activity in youth via organized sports.

National High School Coaches Association (NHSCA)

Website: http://www.nhsca.com
Publication: *Coaches Quarterly Magazine*

A national nonprofit association that centers on the influence and professionalism of coaches and provides insurance coverage and educational programs for its participants.

National Institute for Fitness and Sport (NIFS)

Website: http://www.nifs.org

An Indiana-based nonprofit organization that conducts research for enhancing health and athletic performance and provides physical fitness programs and health and fitness education for individuals and corporations.

National Operating Committee on Standards for Athletic Equipment (NOCSAE)

Website: http://www.nocsae.org
Publication: *NOCSAE Manual*

A committee that develops performance standards for the protective equipment used in a variety of sports and commissions scientific research on the mechanisms of athletic injuries.

National Strength and Conditioning Association (NSCA)

Website: http://www.nsca-lift.org
Publications: *National Strength and Conditioning Association Journal, Journal of Applied Sport Science Research*

An association that promotes and disseminates research on strength and conditioning to improve athletic performance and fitness.

National Youth Sports Safety Foundation (NYSSF)

Website: http://www.nyssf.org

A national nonprofit organization working to minimize the number and severity of sports-sustained youth injuries.

President's Council on Physical Fitness and Sports (PCPFS)

Website: http://www.fitness.gov
Publication: *PCPFS Newsletter*

A volunteer committee working with the U.S. Department of Health and Human Services to engage, educate, and empower Americans of all ages to adopt a healthy lifestyle that includes regular physical activity and good nutrition.

Sport in Society, National University Consortium for Sport in Society

Website: http://www.sportinsociety.org
Publication: *Journal of Sport and Social Issues*

An organization based at Northeastern University that promotes the use of sports to help prevent interpersonal violence, improve the health of impoverished youth, and foster social diversity.

U.S. Consumer Product Safety Commission (USCPSC)

Website: http://www.cpsc.gov

The U.S. federal agency charged with protecting consumers and families from products that may pose a hazard or threat.

Sports

Amateur Athletic Union of the United States (AAU)

Website: http://www.aausports.org
Publication: *InfoAAU*

A national nonprofit, volunteer, multisport organization dedicated to the promotion and development of amateur sports and physical fitness programs.

American Junior Golf Association (AJGA)

Website: http://www.ajga.org
Publication: *AJGA Tour Talk Newsletter*

A nonprofit organization dedicated to the growth and development of competitive junior golfers striving to earn college golf scholarships.

Canada Games Council

Website:
http://www.canadagames.ca

The governing body for the Canada Games: a private, nonprofit organization that promotes ongoing partnerships with organizations at the municipal, provincial, and national levels and provides support in organizational planning, ceremonies, marketing, and sponsorship.

Canadian Association for the Advancement of Women and Sport and Physical Activity (CAAWS)

Website: http://www.caaws.ca/e

An association supporting and promoting women in sport while providing leadership and education.

Canadian Blind Sports Association (CBSA)

Website: http://www.canadianblindsports.ca

The national governing body for goalball, advocating for the blind and visually impaired within the sports system.

Canadian Centre for Ethics in Sports (CCES)

Website: http://www.cces.ca

A nonprofit organization devoted to promoting ethical conduct in sport and responsible for the implementation and management of Canada's Anti-Doping Program.

Canadian Colleges Athletic Association (CCAA)

Website: http://www.ccaa.ca

The national governing body for college sports in Canada.

Canadian Deaf Sports Association (ASSC-CDSA)

Website: http://www.assc-cdsa.com

An organization that supports deaf athletes who meet the requirements for participating in international competitions, especially the Pan American Games for the Deaf, the Deaflympics, and the World Deaf Championships.

Canadian Interuniversity Sport (CIS)

Website: http://www.cis-sic.ca

The national governing body of university sports in Canada, comprising 52 member universities.

Canadian Wheelchair Sports Association (CWSA)

Website: http://www.cwsa.ca/en/site

A national sports organization, founded in 1967, representing wheelchair athletes.

Coaches of Canada

Website: http://www.coachesofcanada.com

The national organization that represents, promotes, and regulates the profession of athletic coaching in Canada.

International Amateur Swimming Federation (IASF)

Website: http://www.fina.org

The world governing body for swimming, diving, water polo, synchronized swimming, and open-water swimming, promoting the development of swimming worldwide.

National Association for Girls and Women in Sports

Website: http://www.aahperd.org
Publication: *The Women in Sport and Physical Activity Journal*

An association within the American Alliance for Health, Physical Education, Recreation and Dance that advocates for girls and women in sports.

National Association for Sport and Physical Education (NASPE)

Website: http://www.aahperd.org/naspe
Publication: *Journal of Physical Education and Recreation*

An association within the American Alliance for Health, Physical Education, Recreation and Dance dedicated to enhancing knowledge and increasing support for quality physical education programs.

National Collegiate Athletic Association (NCAA)

Website: http://www.ncaa.org

The national governing body for intercollegiate athletics in the United States.

National Dance Association (NDA)

Website: http://www.aahperd.org/nda
Publication: *Journal of Physical Education, Recreation, & Dance*

An association that strives to promote quality dance by providing leadership, disseminating research, and collaborating with external partnerships.

National Federation of Interscholastic Coaches Association (NFICA)

An association that aims to improve the athletic participation experience while establishing consistent standards and rules for competition.

National Intramural-Recreational Sports Association (NIRSA)

Website: http://www.nirsa.org
Publications: *NIRSA Journal*, *NIRSA Newsletter*

A research and educational resource for collegiate recreational sports that promotes superior recreational programs, facilities, and services for diverse populations.

Special Olympics

Website: http://www.specialolympics.org

An international organization that holds a competition every 2 years as well as yearlong training for people who have intellectual disabilities.

Special Olympics Canada

Website: http://www.specialolympics.ca

A national nonprofit organization that provides sports training and competition opportunities for athletes with intellectual disabilities.

United States Olympic Committee

Website: http://www.teamusa.org

A committee responsible for training, entering, and underwriting the full expenses for the U.S. teams in the Olympic, Paralympic, Pan-American, and Parapan-American Games, as well as overseeing the process by which U.S. cities seek to be selected as a host to these games.

United States Soccer

Website: http://www.ussoccer.com

The governing body for soccer in the United States, promoting the development of soccer at all recreational and competitive levels.

United States Sports Academy

Website: http://www.ussa.edu

An independent, nonprofit, accredited sports university providing programs in instruction, research, and service to prepare those pursuing careers in the profession of sports.

US Figure Skating (USFS)

Website: http://www.usfsa.org

The national governing body for figure skating and a member of the International Skating Union (ISU) and the U.S. Olympic Committee (USOC), comprising member clubs, collegiate clubs, school-affiliated clubs, and individual members.

USA Athletic Congress (USAAC)

Website: http://www.usaac.org
Publication: *American Athletics Annual*

An association that promotes good sportsmanship by recognizing athletes who have excelled within their respective sports, working in conjunction with international federations and national governing bodies to improve sports participation around the world.

USA Gymnastics

Website: http://www.usa-gymnastics.org

The national organization for gymnastics, encouraging participation and excellence and setting the rules and policies that govern gymnastics in the United States.

USA Swimming

Website: http://www.usaswimming.org

The national governing body for swimming in the United States.

USA Volleyball

Website: http://www.usavolleyball.org

The national governing body for volleyball in the United States.

Women's Sports Foundations (WSF)

Website: http://www.womenssportsfoundations.org
Publications: *Women's Sports and Fitness, Headway*

A foundation that advocates for equal opportunity for women in sports, focusing on the psychological, physical, and social benefits of sports participation.

Sports Medicine

Academy for Sports Dentistry (ASD)

Website: http://www.academyforsportsdentistry.org
Publication: *Sports Dentistry Newsletter*

A forum for medical professionals, coaches, and trainers to exchange ideas pertinent to sports dentistry, as well as for the collection and dissemination of research regarding the prevention and occurrence of dental injuries among athletes.

American Academy of Orthopaedic Surgeons (AAOS)

Website: http://www.aaos.org
Publications: *AAOS Report*, *The Bulletin*

An association of musculoskeletal specialists that provides education and practice management services for orthopedic surgeons and allied health professionals, advocates for enhanced patient care, and disseminates orthopedic knowledge to the public.

American Academy of Pediatrics (AAP) Committee on Sports Medicine & Fitness (COSMF)

Website: http://www.aap.org/sections/sportsmedicine

A division of the American Academy of Pediatrics, providing educational programs, policy statements, collaborative partnerships, media outreach, advocacy work, and research awards to promote safe physical activity and the highest level of treatment in pediatrics.

American Academy of Physical Medicine and Rehabilitation (AAPMR)

Special Interest Group on Sports Medicine

Website: http://www.aapmr.org
Publications: *Archives of Physical Medicine and Rehabilitation*, *Journal of Physical Medicine*

An academy representing patients with, or at risk for, temporary or permanent disabilities and helping physicians acquire the continuing education, practice knowledge, leadership skills, and research findings needed to provide quality patient care.

American Academy of Podiatric Sports Medicine (AAPSM)

Website: http://www.aapsm.org

An academy that helps further the understanding, prevention, and management of lower extremity injuries in sports through professional education, scientific research, public awareness, and membership support.

American College of Sports Medicine (ACSM)

Website: http://www.acsm.org
Publications: *Medicine and Science in Sports and Exercise*, *Sports Medicine Bulletin*, *Exercise and Sport Sciences Reviews*

An association that promotes healthy lifestyles through the diagnosis, treatment, and prevention of sports-related injuries as well as the advancement of exercise science and the dissemination of research.

American Medical Society for Sports Medicine (AMSSM)

Website: http://www.amssm.org

A forum for primary care sports medicine physicians to promote professional relationships and advance the discipline of sports medicine through education, research, advocacy, and quality patient care.

American Optometric Association (AOA) Sports Vision Section (SVS)

Website: http://www.aoa.org/x4787.xml
Publication: *SVS News and Views*

An association that is specific to optometric sports vision, striving to advance care through education, injury prevention, and enhancement of visual performance.

American Orthopaedic Society for Sports Medicine (AOSSM)

Website: http://www.sportsmed.org
Publication: *American Journal of Sports Medicine*

A national organization of orthopedic surgeons committed to sports medicine education, research, communication, and fellowship.

American Osteopathic Academy of Sports Medicine (AOASM)

Website: http://www.aoasm.org
Publication: *Clinical Journal of Sports Medicine*

An educational forum for primary care physicians and health care professionals to attend to the quality of health care, promoting fitness and exercise guidelines and providing a collegial environment to expand the knowledge of sports medicine.

American Physical Therapy Association (APTA)

Website: http://www.apta.org
Publication: *Physical Therapy*

A national organization committed to the advancement of physical therapy practice and research, promoting the prevention, diagnosis, and treatment of movement dysfunctions and the improvement of the physical health and functional abilities of all members of the public.

British Association of Sport and Exercise Medicine (BASEM)

Website: http://www.basem.co.uk

The oldest sport and exercise medicine association in the United Kingdom (founded in 1953) and the official UK representative to both the European Federation of Sports Medicine Associations (EFSMA) and the International Federation of Sports Medicine (FIMS), dedicated to the promotion of good health through physical activity and the provision of sports medicine expertise to optimize athletic performance at all levels.

Canadian Academy of Sports Medicine (CASM-ACMS)

Website: http://www.casm-acms.org

An organization of physicians dedicated to the practice of medicine as applied to all aspects of physical activity, including health promotion and disease prevention.

Canadian Athletic Therapists Association (CATA)

Website: http://www.athletictherapy.org/en/index.aspx

A nonprofit organization dedicated to promoting injury prevention, emergency services, and rehabilitative techniques for active individuals.

Canadian Physiotherapy Association (CPA)

Website: http://www.thesehands.ca

An association of physiotherapists, physiotherapy support workers, physiotherapy students, and affiliate members dedicated to advancing the field of physiotherapy and improving the health of all individuals.

Canadian Society for Exercise Physiology (CSEP)

Website: http://www.csep.ca
Publication: *Canadian Journal of Applied Physiology*

An organization of professionals involved in the scientific study of exercise physiology, exercise biochemistry, fitness, and health.

Gatorade Sports Science Institute (GSSI)

Website: http://www.gssiweb.com

A research and educational facility that studies with scientists around the world the effects of exercise, the environment, and nutrition on the human body.

International Federation of Sports Medicine (FIMS)

Website: http://www.fims.org

An international organization dedicated to the study of sports medicine as well as the dissemination of findings to help athletes maximize their potential.

International Society of Arthroscopy, Knee Surgery, and Orthopedic Sports Medicine (ISAKOS)

Website: http://www.isakos.com

An international society that provides a forum for surgeons to advance the exchange and dissemination of information on education, research, and patient care in arthroscopy, knee surgery, and orthopedic sports medicine.

National Collegiate Athletic Association (NCAA) Committee on Competitive Safeguards and Medical Aspects of Sports

Website: http://www.ncaa.org
Publications: *The Sports Medicine Handbook*, *Injury Surveillance Annual Report*

A committee whose mission is to provide expertise and leadership to the NCAA to help it promote a healthy and safe environment for student-athletes through research, education, collaboration, and policy development.

Society for Adolescent Medicine (SAHM)

Website: http://www.adolescenthealth.org
Publication: *Journal of Adolescent Health Care*

A multidisciplinary organization of health professionals with the common goal of understanding the health needs and concerns of adolescents and enhancing public awareness through education, research, clinical services, and advocacy activities.

Sport Physiotherapy Canada

Website: http://www.sportphysio.ca

An organization, founded in 1972, dedicated to providing therapy, rehabilitation, and counseling to athletes before, during, and after injury.

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